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CURAT: L. JAKUCS

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To the memory of Professor Dr G. Péczely

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THE GLOBAL SYSTEM OF WATER VAPOUR QUANTITY IN THE ATMOSPHERE AND ITS YEARLY ALTERATION

by

G. Péczely

A légköri vízgőz mennyiségének földgömbi rendszere és évi változása. A tanulmányban leírt számítási módszer alapján bemutatásra kerül a légköri vízgőz tömegének és éven belüli változásának földgömbi eloszlása. A számítások 714 állomás éghajlati adatai alapján készültek, figyelembe véve az óceáni és poláris területekről származó legújabb éghajlati átlagokat is. A Föld légköre évi átlagban $1{,}352\,26 \cdot 10^{16}$ kg tömegű vízgőzt tartalmaz, ami egyenletes eloszlásban 26,5 kg/m² vízmennyiséget jelent. A légköri vízgőzkészlet éven belüli változása Földünk monszunterületein a legjelentősebb, míg a legcsekélyebb éven belüli változás az egyenlítői övben, valamint a csekély párolgással rendelkező sivatagos és sarkvidéki területeken tapasztalható.

On the basis of a calculation method described in present study it was aimed to represent the within year alteration and terrestrial distribution of atmospheric water vapour contents. Calculations are based on weather data obtained from 714 stations considering at the same time recent climatological averages originating from oceanic and polar zones. The atmosphere of the Earth contains $1{,}352\,26 \cdot 10^{16}$ kg water vapour as a yearly average, which in a uniform distribution means 26.5 kg/m² quantity of water. The greatest alteration in atmospheric water vapour supply takes place in monsoon areas of the Earth, while the smallest changes can be experienced in the equatorial zone as well as in desert and polar territories with low evaporation rates.

1. Introduktion

Two methods can be used to explore the average water vapour quantity in the atmosphere:

1. From the average values of vapour pressure measured near the soil the water vapour contents of an air column can be calculated.

2. On the basis of measurements in the high atmosphere the mass of water vapour profile in the air column above a given point of observation can be calculated.

Latter method without doubt offers more exact results, its disadvantage is that such data is available only from relatively few places and for short periods, this way it assures only an approaching estimation of water vapour contents of the atmosphere and a superficial exploration of its structure of distribution. Even in our days for a more detailed geographical analysis the adoption of method 1 can be reccomended.

Empiric relationships are known explaining the height function z of vapour pressure e concretizing the function

$$e_z = f(e_0, z) \tag{1}$$

where e_0 means vapour pressure near the soil. Taking *average values* an approximatively satisfying exactness is assured by the formula *Süring*, according to which:

$$e_z = e_0 \cdot 10^{-z/6(1+(z/20))} \tag{2}$$

where z represents height in km-s.

If a 1 m² cross-sectional air column (length: $z=0$ to z) is divided into Δz wide sections while taking into account the average T_0 temperature at $z=0$ level (level of the soil) and the temperature profile z $T_z = T_0$ generally valid for the troposhere (according to data of normal atmosphere if z is expressed in km it equals 6,50) this way $z = z_2 - z_1$ layer's average vapour pressure e and its average T temperature can be calculated on the basis of e_0 and T_0. After having calculated e and T the water vapour mass s of one unit cross-sectional and z wide air layer is given by the following, already known formula:

$$s(\mathrm{kg}\cdot\mathrm{m}^{-3}) = \frac{0{,}217e}{T}\Delta z \tag{3}$$

where e is expressed in units of hectopascal (mbar) while T in °Kelvin and z in meters.

The mass of the water vapour quantity of the whole air column is expressed by the following integral:

$$\underset{(\mathrm{kg}\cdot\mathrm{m}^{-3})}{S} = \int_0^z f(s)\,dz \tag{4}$$

which is considered in practical calculations on the basis of water vapour mass s summarized for layers of z. The integral (4) gives the quantity of precipitable water from an air column of one unit cross-section.

As an upper limit of integration in our calculations the heighths of tropopause referring to normal atmosphere was considered, i. e. $z=11$ km value was uniformally accepted for the whole surface of the Earth. Because the height of the points of observation is different and not uniformally 11 km but 11—h km high, so the water vapour mass of one unit cross-sectional air column has to be considered in 11—h height above sea level meaning h expressed in kilometers.

Generally, it can be stated, that

$$S = F_1(e_0, T_0, h) \tag{5}$$

and

$$S(\mathrm{kg}\cdot\mathrm{m}^{-2}) = \alpha\cdot e_0 \tag{6}$$

where

$$\alpha = F_2(T_0, h). \tag{7}$$

A graphical demonstration of empirically defined values of function (7) is represented in *Fig. 1.*

To determine the global distribution of water vapor in the atmosphere the monthly mean e_0 and T_0 values from 714 stations were considered. These average values refer mostly to the period between 1931 and 1960, though from polar and oceanic territories 5—10 year old normal values were necessarily used in order to obtain a net of sufficient density.

From the averages of monthly water vapour quantities the yearly mean water quantity was determined as well $S = S_{max} - S_{min}$ difference characterising the yearly circulat ion of water vapour, where S_{max} represents the maximal value of monthly average water vapour content and S_{min} its minimal value.

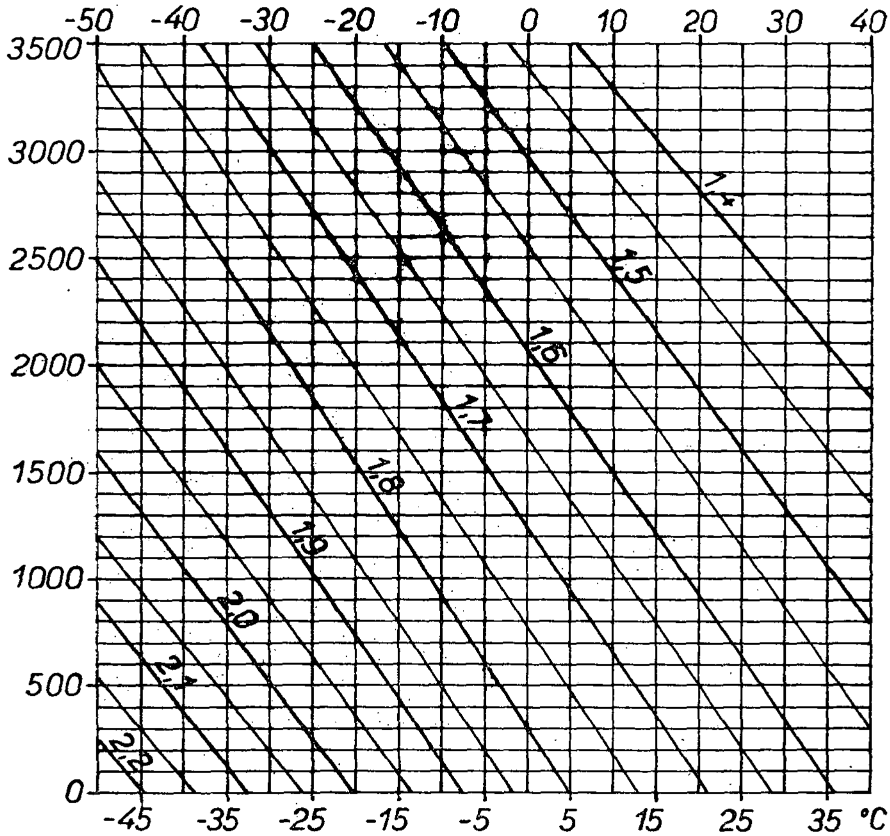

Fig. 1. Aid to determine atmospheric water vapour contents

2. Terrestrial distribution of water vapour contents of the atmosphere

The terrestrial system of water vapour contents in the atmosphere can be most concisely characterised by its yearly average value *(Fig. 2.)*

A temperature zonal system is at once conspicuous. The overwhelming part of the torrid zone is characterised by a water vapour contents above 45 kg/m^2, and on the most water vaporous territories between 50—55 kg/m^2 can be found (Western part of equatorial zone of the Pacific, Eastern part of the Indian Ocean around the Equator, Pacific coast of Columbia).

Lowest water vapour contents due to constantly low temperatures can be found in polar territories where its yearly average value does not reach 2 kg/m^2, moreover above the inner plateau of the Antarctic, which lies in a great height, is even less than 1 kg/m^2. Characteristic water vapour-arm territories emerged at low and middle geographical latitudes in inner and high territories of great continents as well (in Asia the highland of Tibet, the Iran basin, in Africa the central territories of the Sahara, in North-America the basins between the Coastal Mountains and the Rocky Moun-

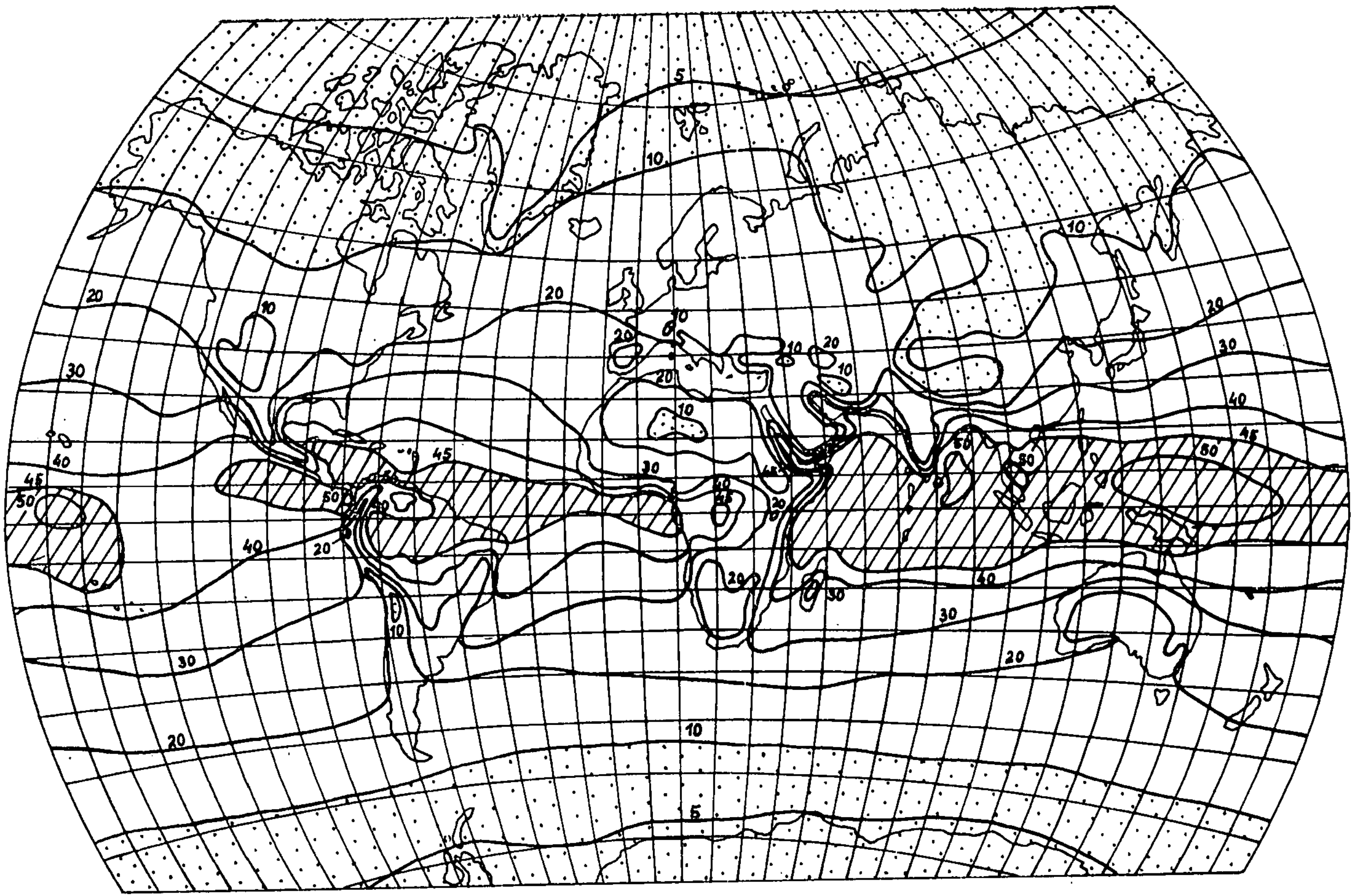

Fig. 2. Terrestrial distribution of yearly average of atmospheric water vapour contents (kg/m²)

tains (the yearly average water vapour contents value remains below 10 kg/m^2. On the basis of this data the water vapour contents of the different terrestrial zones can be calculated and by summing up the obtained results the mass of the total quantity of water vapour in the atmosphere can be deducted. This data is illustrated in *Table 1*.

Table 1

Zonal Distribution of Atmospheric Water Vapour (S)

	S(10^{14} kg)
90°—80° N	0,160
80°—70°	0,693
70°—60°	1,730
60°—50°	3,221
50°—40°	5,316
40°—30°	8,230
30°—20°	12,203
20°—10°	16,727
10°— 0°	19,780
0°—10° S	19,585
10°—20°	16,452
20°—30°	12,477
30°—40°	8,838
40°—50°	5,617
50°—60°	2,879
60°—70°	1,049
70°—80°	0,247
80°—90°	0,022
Earth	135,226

The mass of water vapour contents in our atmosphere is $135{,}226 \cdot 10^{14}$ kg in one year, which means 26,5 kg/m^2 water quantity in a uniform distribution. 50% of this water vapour quantity can be found in the torrid zone limited by 19° N and 18° S longitudinal degrees, and only its 10% can be found in the atmosphere between 90° N—47° N and 90° S—44° S degrees.

3. Within year modifications of water vapour contents of the atmosphere

The numerical value characterising the yearly circulation of water vapour is given by the difference of maximal and minimal monthly averages. The modification of atmospherical water vapour contents within a year is caused by two factors. A decisive role is played by the yearly alteration of temperature, since if the temperature rises, the air's capability to accomodate vapour increases too. In some of the sections the advection of water vapour appears to be a significant factor. This means transportation of water vapour from faraway territories which gives as a result a greater alteration in water vapour contents within a year than explained with the annual modification of temperature. In territories where water in the covering layer of the soil is limited there is no, or if at all, a reduced water supply ensuring evaporation, the yearly alteration of water vapour contents becomes less as justified by the rate of temperature change.

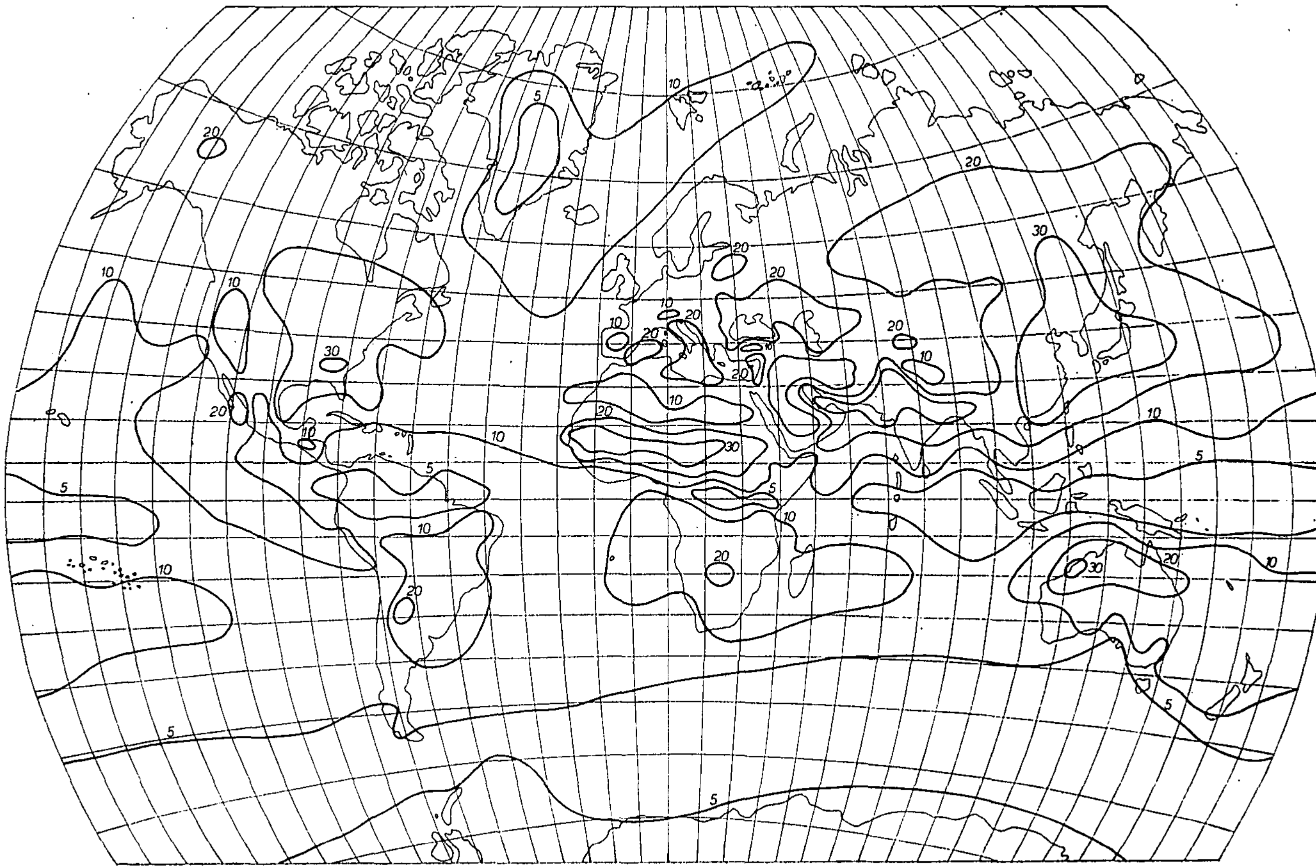

Fig. 3. Yearly terrestrial distribution of atmospheric water vapour content changes (kg/m²)

A survey of the global system of this process can be observed in *Fig. 3.* denominating $S = S_{max} - S_{min}$ values. The within year alteration of water vapour contents appears to be the greatest (30 kg/m^2) in monsoon territories of East and South Asia, Central Africa, Australia and North America where the water advection activity is quite high during the summer months. The smallest within year alteration (5 kg/m^2) was found in the equatorial zone with constant temperature, in the dry deserts and in the polar zones with low evaporation (inner areas of Antarctic and Greenland).

EXPANSION OF METEOROLOGICAL FIELDS BY MACROSYNOPTIC AVERAGE FIELDS

by

*Judith Bartholy**—*O. Gulyás**

Meteorológiai mezők sorfejtése makroszinoptikus átlagmezők alapján. A tanulmány az atlanti-európai térségben 5° szélességkülönbséggel és 10° hosszúságkülönbséggel felvett pontok által meghatározott rácson az AT 500-as geopotenciál mezők optimális reprezentációjával foglalkozik s kísérletet tesz arra is, hogy megalkossa a makroszinoptikus mezőknek a Péczely-féle típusokkal analóg módon definiált alaprendszerét.

A dolgozatban megoldott feladat a közép- és hosszútávú előrejelzés szempontjából gyakorlati jelentőségű is.

The study is dealing with optimal representation of the AT 500 geopotential fields given by grid points with 5° latitude difference and 10° longitude difference. At the same time it attempts to compose a basic system of the macrosynoptic fields defined on the analogy of the Péczely-types.

The problem solved in the study has got practical importance in the respect of middle-range and long-range weather forecast.

Introduction

Generally it is difficult to describe meteorological fields, weather situations with high accuracy, in practice they are given as interpolated values on grid points or as values measured on meteorological stations. They are demonstrated by isolines on weather maps. In consequence of the increasing role of computers, spreading of the computer science and data banks it became an important requirement to represent meteorological fields with numbers, that is to associate a vector $(a_0, a_1, a_2, \ldots, a_N)$ with a meteorological object. Usually when choosing codes to be used the following factors are considered:

i) Using the codes the field should be reconstructable with required accuracy.

ii) Possibly only a few numbers should be used in coding.

iii) The codes should be easily calculated.

iv) The field should be interpretable, physically explainable and analyzable in coded form, too.

Accordingly, function series are applied as field representation methods, such as Fourier-expansion, approximation with Chebishev series, Shannon—Kotelnikov representation, and mainly in meteorology, natural orthogonal expansion. Applying the different expansions the coding requirements cannot be fulfilled simultaneously, because these requirements are usually contradictive. The known expansions are generally favourable from one point of view, while the other requirements are usually partially fulfilled. Thus in meteorology the often used natural orthogonal expansion

* Hungarian Meteorological Service

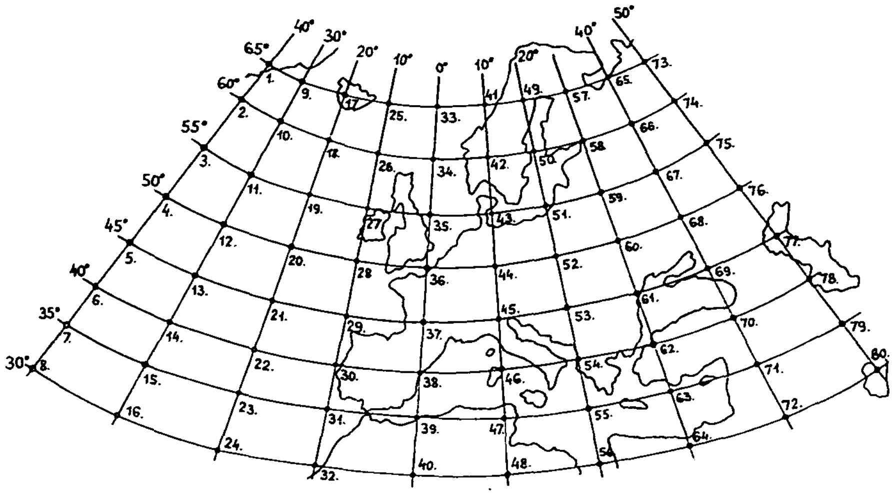

Fig. 1. Grid network ower the Atlantic European area

(*Craddock—Flood*, 1969) is optimal as to the numbers of codes, while at the same time, it is not simple to calculate the coefficients and to interprete the field in coded form.

This paper describes an expansion method which produces the field with relatively few coefficients, by a physically well interpretable system. The procedure was used for describing the 500 mbar isobaric surface, (hPa).

The system of average fields

In the suggested method the field

$$\xi(\mathbf{r}) = a_0 + a_1 e_1(\mathbf{r}) + a_2 e_2(\mathbf{r}) + \ldots + a_N e_N(\mathbf{r}), \tag{1}$$

may be given by the coefficient system:

$$(a_0, a_1, a_2, \ldots, a_N) \tag{2}$$

where $\{e_i(\mathbf{r})\}$ is a given field defined on R^3. In case of natural orthogonal expansion $\{e_i(\mathbf{r})\}$ consists of the eigenvectors of the covariance matrix of the field, and in our suggested method $\{e_i(\mathbf{r})\}$ equals to the 500 mbar isobaric field, averaged over the days with equivalent macrosynoptic code. As later is shown, it is not an orthogonal system, but linearly independent. Our results show — though it is surprising — that relatively small numbers of codes are needed to produce practical accuracy and the expansion has physical content at the same time.

500 mbar isobaric surface were used during the investigations by grid points, on an area represented on the chart below:

The data were obtained from the data bank of the British Meteorological Service. All 500 mbar isobaric surface daily values were used between 1955—1966. The data were read from the charts of Deutscher Wetterdienst, and after being interpolated for the grid points and being arranged they were recorded on magnetic tape.

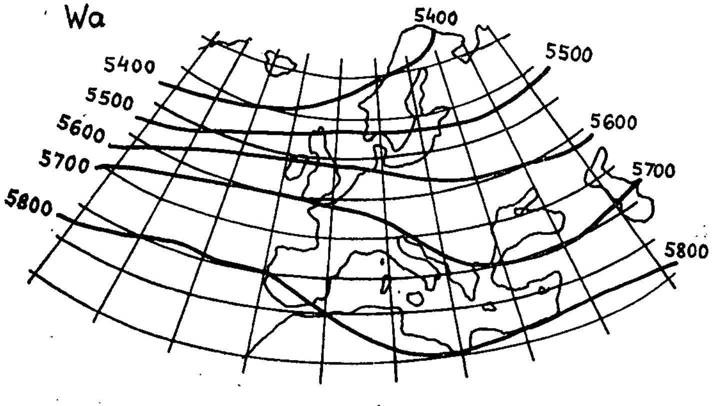

Fig. 2.1. Wa, Anticyclonic Western situation

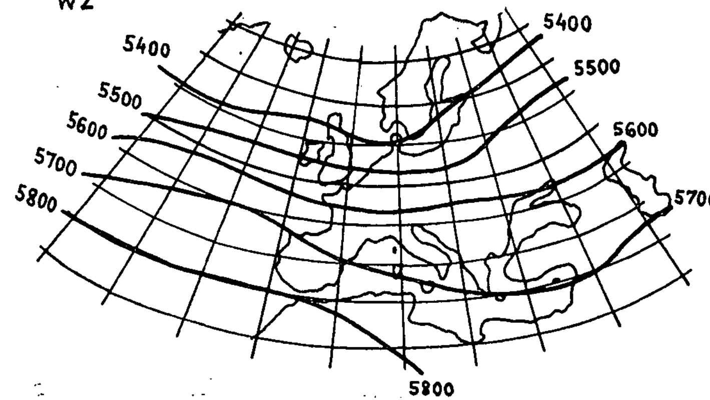

Fig. 2.2. Wz, Cyclonic Western situation

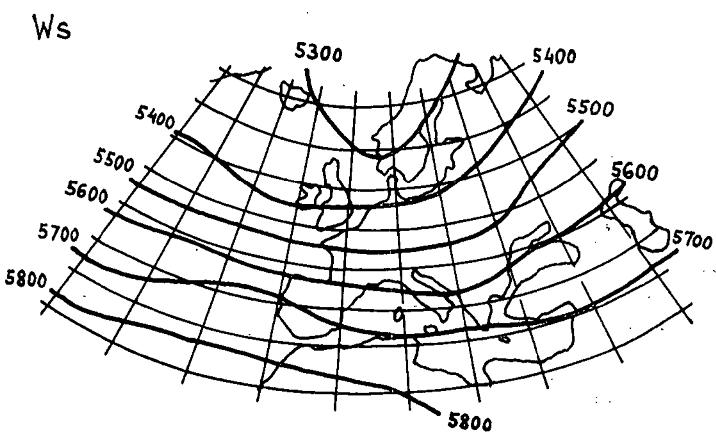

Fig. 2.3. Ws, South-Western situation

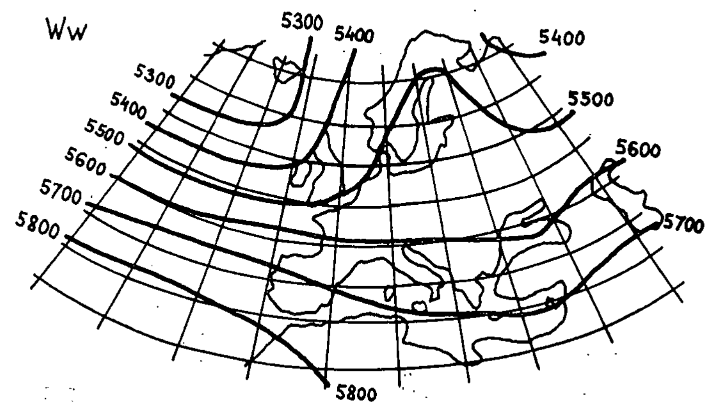

Fig. 2.4. Ww, Sharply edged Western situation

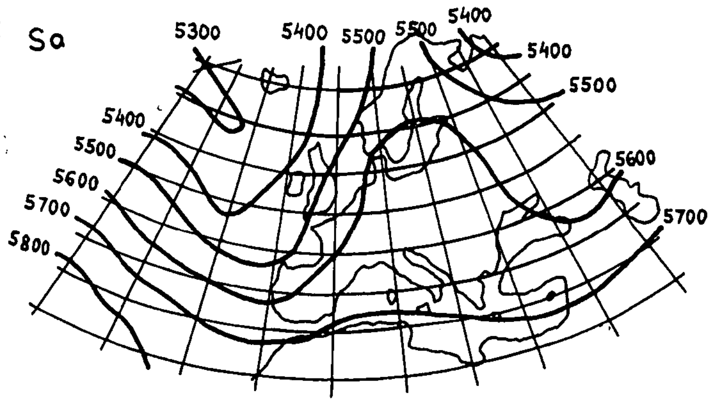

Fig. 2.5. Sa, Anticyclonic Southern situation

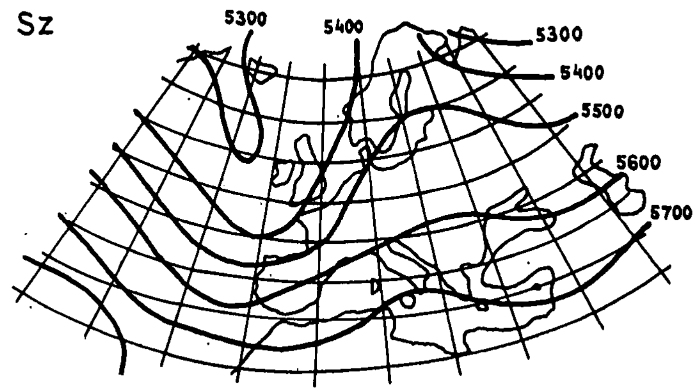

Fig. 2.6. Sz, Cyclonic Southern situation

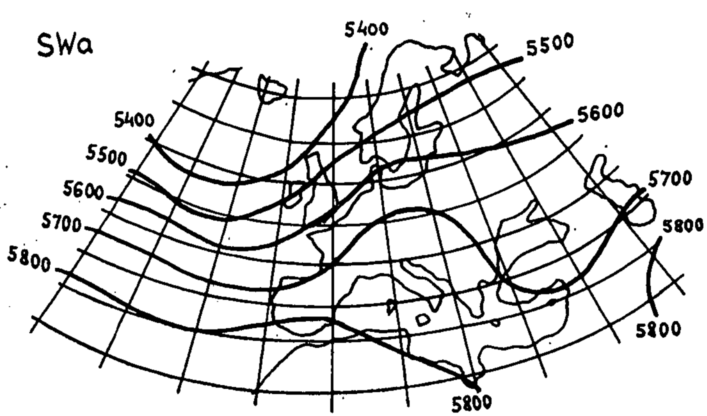

Fig. 2.7. SWa, Anticyclonic South-Western situation

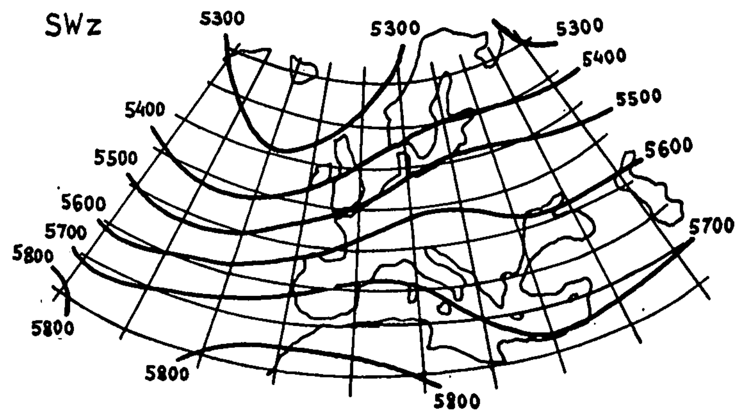

Fig. 2.8. SWz, Cyclonic South-Western situation

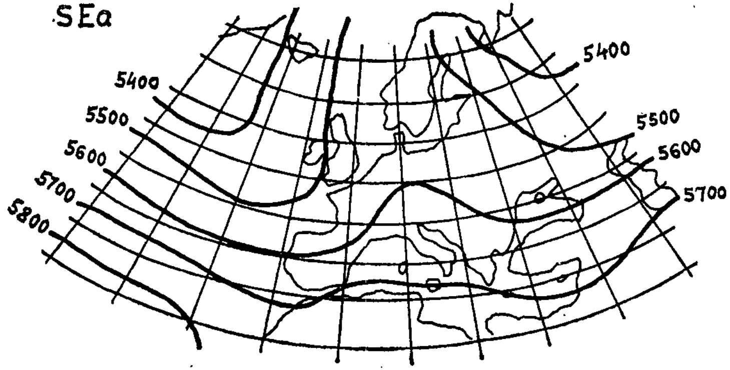

Fig. 2.9. SEa, Anticyclonic South-Eastern situation

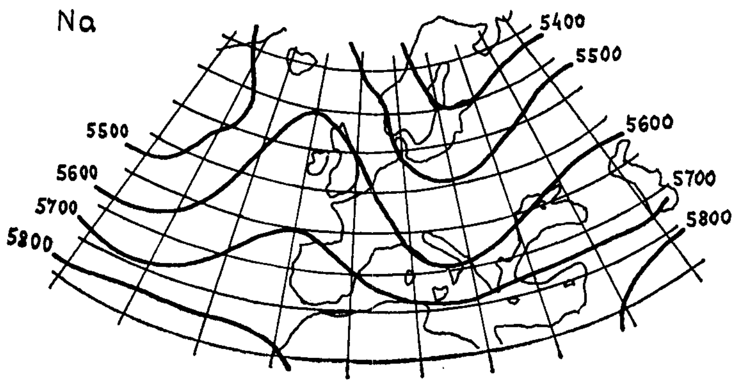

Fig. 2.10. SEz, Cyclonic South-Eastern situation

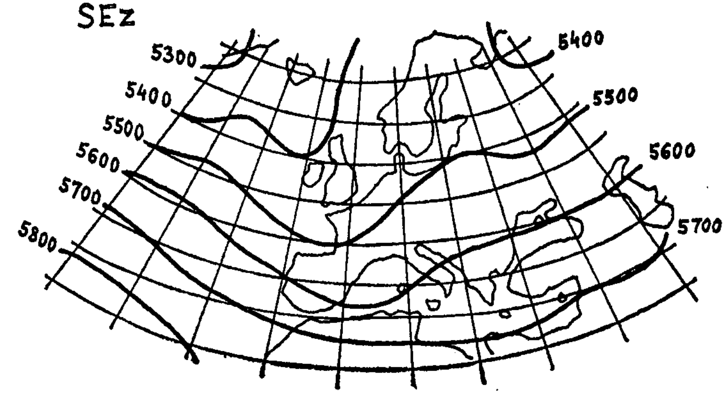

Fig. 2.11. Na, Anticyclonic Northern situation

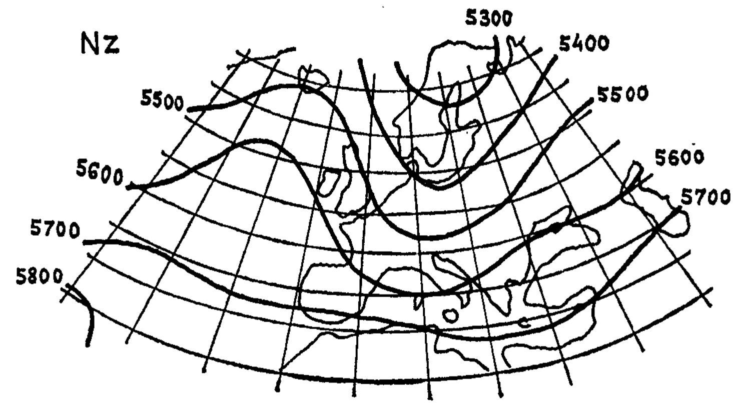

Fig. 2.12. Nz, Cyclonic Northern situation

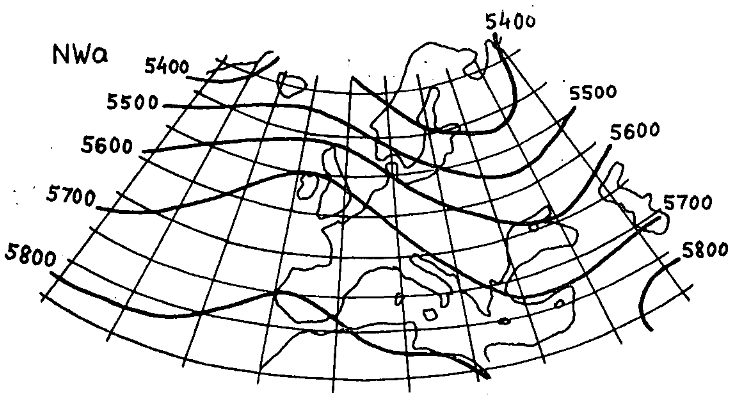

Fig. 2.13. NWa, Anticyclonic North-Western situation

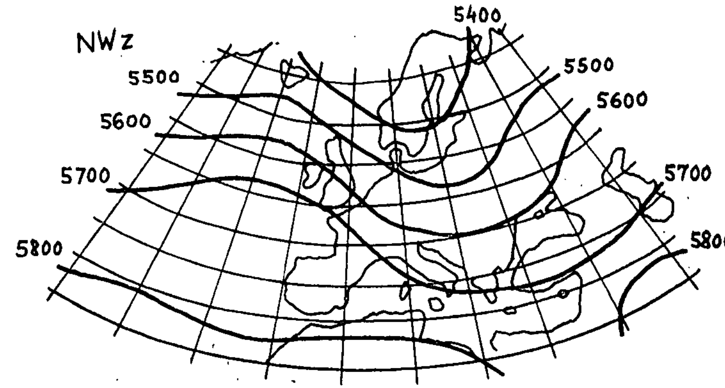

Fig. 2.14. NWz, Cyclonic North-Western situation

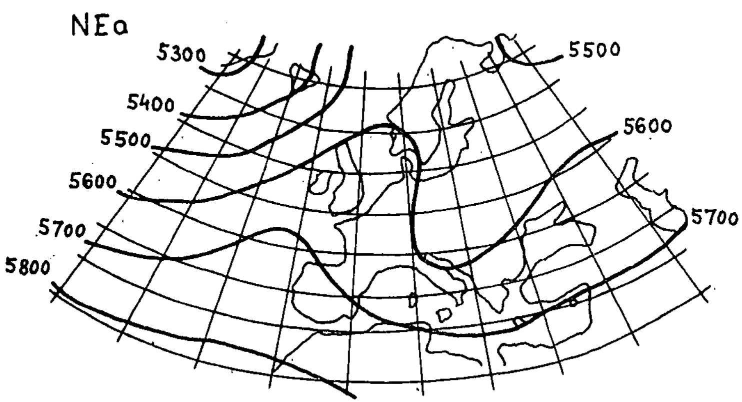

Fig. 2.15. NEa, Anticyclonic North-Eastern situation

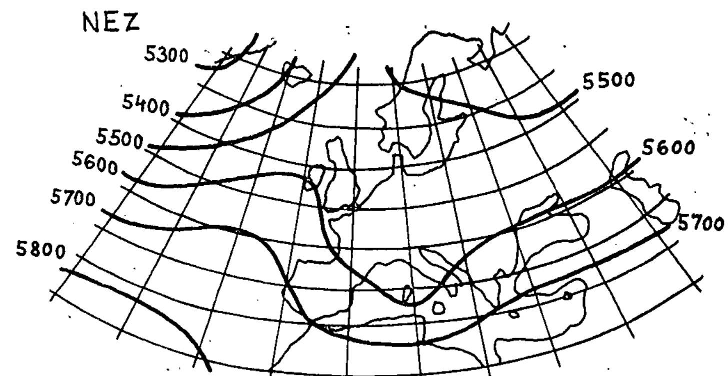

Fig. 2.16. NEz, Cyclonic North-Eastern situation

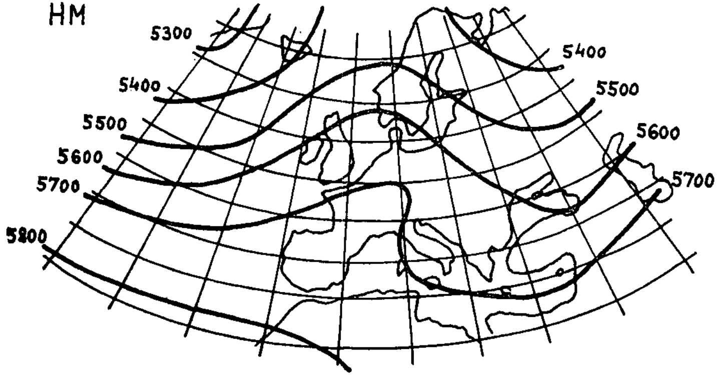

Fig. 2.17. HM, High pressure over Central-Europe

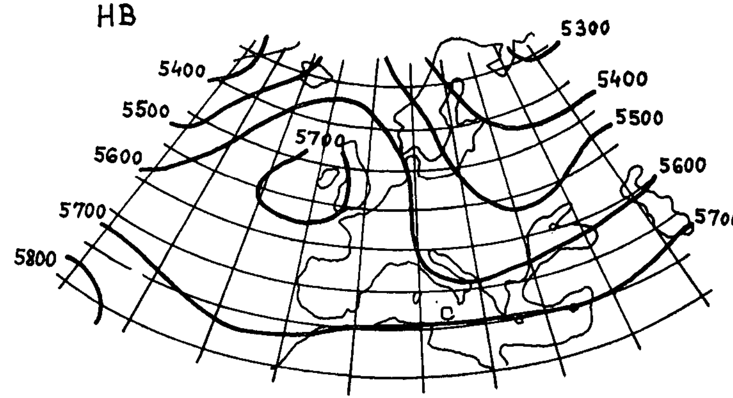

Fig. 2.18. HB, High pressure centre over Britain

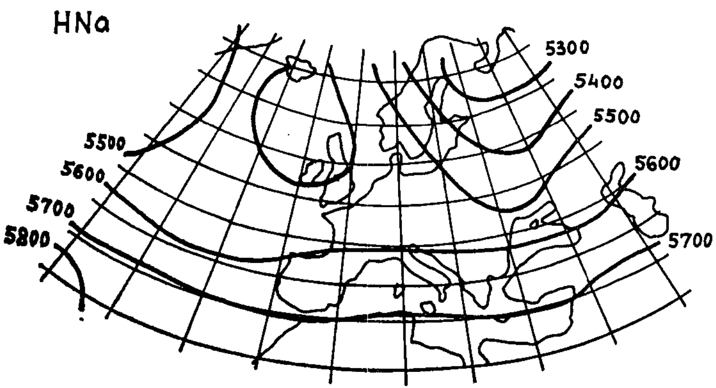

Fig. 2.19. HNa, High pressure centre on the Northern Sea, developing over Central-Europe

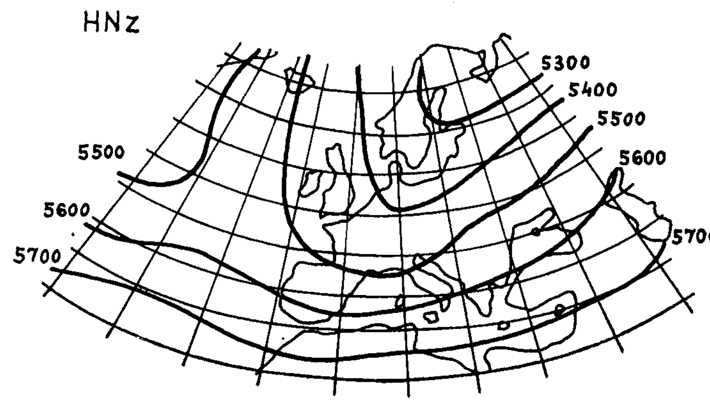

Fig. 2.20. HNz, High pressure on the Northern Sea

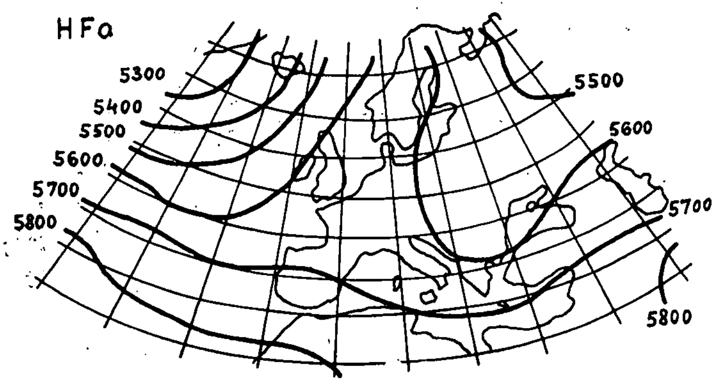

Fig. 2.21. HFa; High pressure on Fenno-Scandinavia developing over Central-Europe

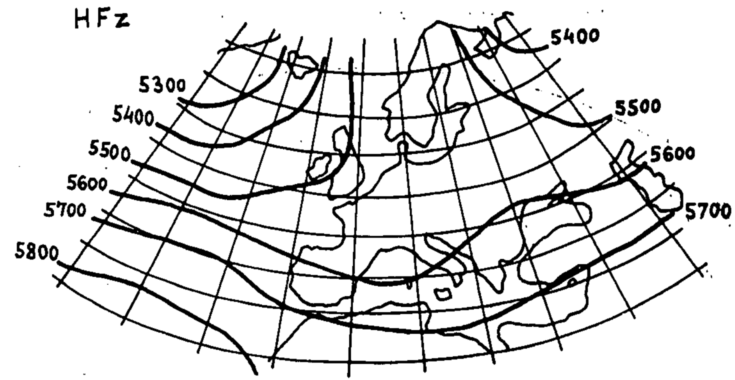

Fig. 2.22. HFz, High pressure on Fenno-Scandinavia and low pressure over Central-Europe

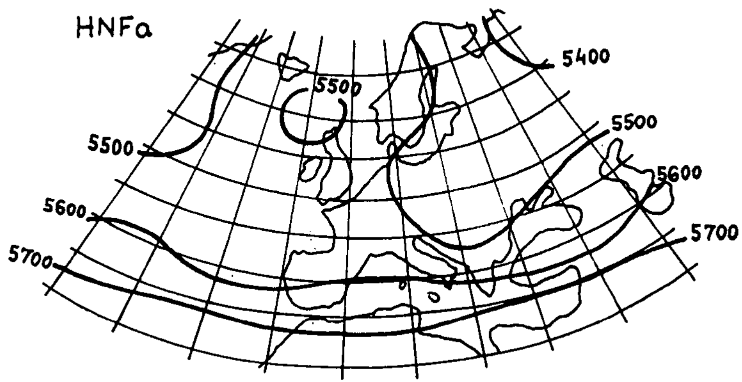

Fig. 2.23. HNFa, High pressure on the Northern Sea and Fenno-Scandinavia, developing over Central-Europe

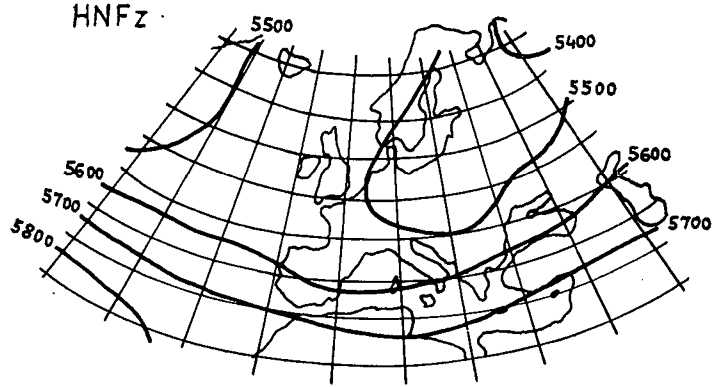

Fig. 2.24. HNFz, High pressure on the Northern Sea and Fenno-Scandinavia and low pressure over Central-Europe

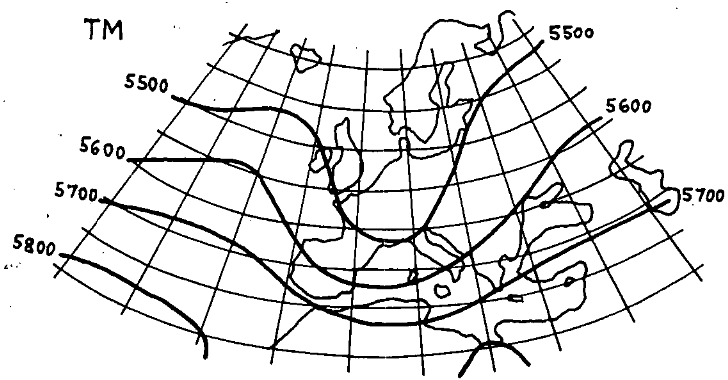

Fig. 2.25. TM, Low pressure over Central-Europe

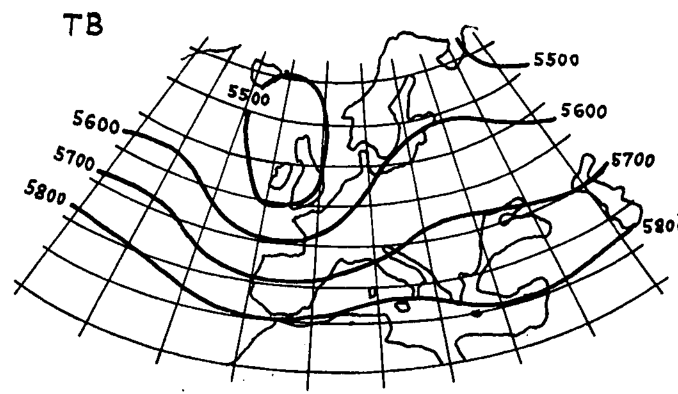

Fig. 2.26. TB, Low pressure centre over Britain

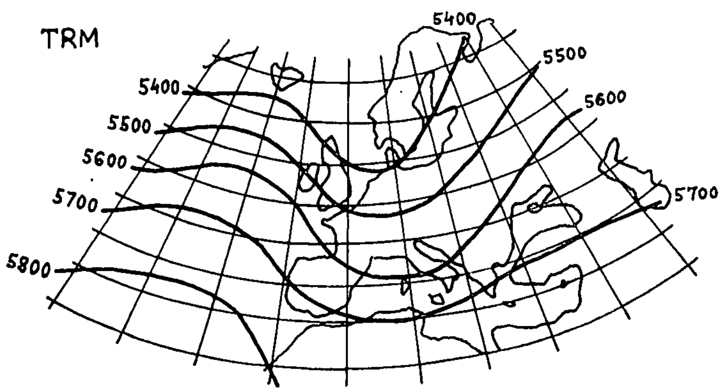

Fig. 2.27. TRM, Trough over Central-Europe

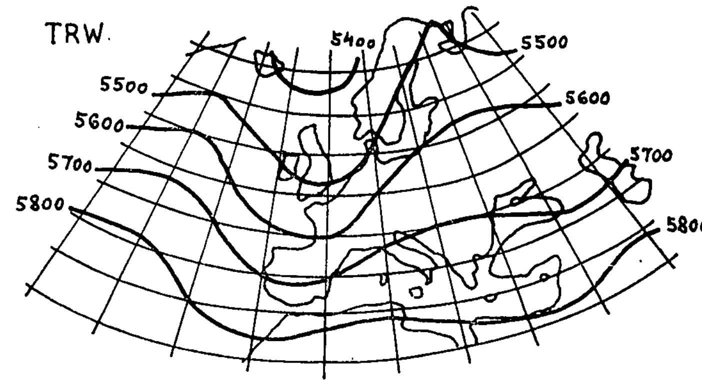

Fig. 2.28. TRW, Trough over Western-Europe

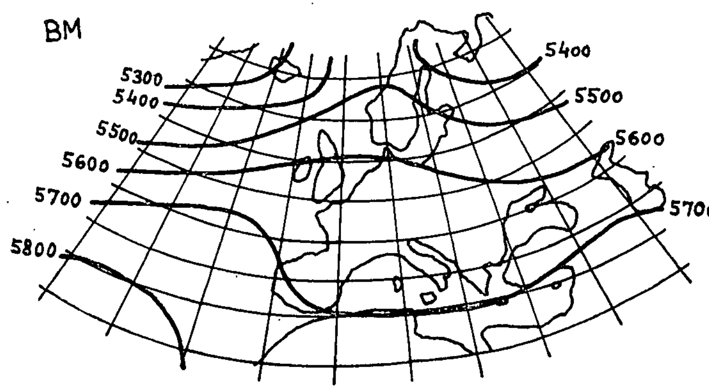

Fig. 2.29. BM, Zonal circulation with high ridge over Central-Europe

Therefore the i-th day can be given by a 80-vector:

$$\mathbf{x}_i = (x_{i1}, x_{i2}, \dots, x_{i80}), \quad i = 1, 2, \dots, 4018 \tag{3}$$

where x_{ij} denotes the value of the i-th day in the j-th grid point. The fields were grouped in according to macrosynoptic codes. The macrosynoptic codes were given from the above mentioned data bank, too. Being arranged according to the Hess—Brezowsky's macrosynoptic codes, (*Hess—Brezowsky*, 1952) the 500 mbar isobaric surface devided into 30 groups. The average fields, i. e. the fields averaged over each group were calculated and they served as the function system $\{e_i(\mathbf{r})\}_{i=1}^{30}$ in the new expansion. On the basis of this, each element of the system corresponds to a well defined meteorological situation. The following figures 2.1.—2.30. represent these Hess—Brezowsky's average fields. The obtained average fields $\{e_i(\mathbf{r})\}_{i=1}^{30}$ were analyzed and they were found suitable for expansion, and the fields were expansed by the function system $\{e_i(\mathbf{r})\}_{i=1}^{30}$.

Expansion by the average fields

Our task is to give the field $\xi(\mathbf{r})$ with the following series:

$$\xi(\mathbf{r}) = a_0 + a_1 e_1(\mathbf{r}) + a_2 e_2(\mathbf{r}) + \dots + a_N e_N(\mathbf{r}) \tag{4}$$

where $e_i(\mathbf{r})$ is the function system derived from 500 mbar AT fields averaged over the days with equivalent macrosynoptic codes. For the sake of possible interpretation of this series the function system should be linearly independent and complete. The coefficient system will be unique and the total accuracy can be achieved theoretically, too. The linear independence can be checked directly. As it is well known from the Vector Algebra the vector system $(e_1, e_2, \dots, e_N)$ is linearly independent if and only if the Gram determinant form of the scalar products (e_i, e_j) is not 0. This condition was tested, and it was proved correct.

The steps of the expansion:

i) The system of the average fields $\{e_i(\mathbf{r})\}$ belonging to the macrosynoptic codes is transformed into an orthonormal vector system $\{e_i^*(\mathbf{r})\}$ by means of Hilbert—Schmidt's orthogonal procedure (as it is known, the only essential and controlled condition is the linear independence of the system $\{e_i(\mathbf{r})\}$).

ii) The actual examined field is expansed by the obtained system $\{e_i^*(\mathbf{r})\}$, thus

$$\xi(\mathbf{r}) = a_0^* + a_1 e_1^*(\mathbf{r}) + a_2 e_2^*(\mathbf{r}) + \dots + a_N e_N^*(\mathbf{r}) \tag{5}$$

where

$$a_i^* = \left(\xi(\mathbf{r}), e_i^*(\mathbf{r})\right) = \sum_{j=1}^{M} \xi(r_j) a_i^*(r_j). \tag{6}$$

iii) There is a linear relationship between the coefficients of the expansions e_i and e_i^*, which is described by the following equation system:

$$\begin{aligned}
(e_1^*, e_1)a_1 + (a_1^*, e_2)a_2 + \dots + (e_1^*, e_M)a_M &= a_1^* \\
(e_2^*, e_1)a_1 + (e_2^*, e_2)a_2 + \dots + (e_2^*, e_M)a_M &= a_2^* \\
\vdots \qquad\qquad & \quad \vdots \\
(e_M^*, e_1)a_1 + (e_M^*, e_2)a_2 + \dots + (e_M^*, e_M)a_M &= a_M^*.
\end{aligned} \tag{7}$$

Solving this equation system the coefficient vector will be given, and also the series determined by it:

$$\xi(\mathbf{r}) = a_0 + a_1 e_1(\mathbf{r}) + \ldots + a_M e_M(\mathbf{r}). \tag{8}$$

As regards the completeness it can be tested only in empirical way. It is clear that a system consisting of 30 elements cannot be complete in the 80 dimensional Euclidean space. But the fields taken into consideration do not fill up the whole space. However the obtained subspace cannot be defined exactly. That is why we had to restrict ourselves to carrying out the expansions in the examined fields — at least in a part of them — and to estimating the accuracy of the reproduction. This investigation gave much better results than we expected. In order to illustrate our results an original 500 mbar isobaric field and its reproduced form gained by the coefficient of the expansion in the Hess—Brezowsky's system (the date: January 1, 1962) is shown in *Figure 3.*

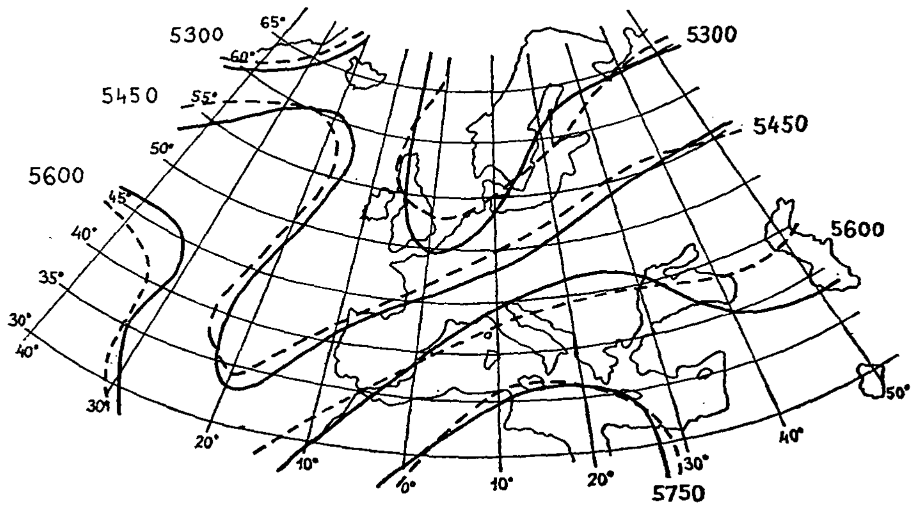

Fig. 3. 500 mbar isobaric field (1st January, 1962) before the expansion (black line), and its reconstructed form after the expansion (dotted line)

The expansional pattern was carried out for 30 days and it was found that the difference between the original field and the field reproduced by the obtained coefficients could be measured in decametres which does not exceed the inaccuracy in radiosonde measurements. (It is not necessary that the accuracy of the computed values should exceed the accuracy of the input field-data measured by radiosondes.) The expansion of the 500 mbar isobaric surface field was performed not only by the use of Hess—Brezowsky's average field system. The expansion was also done using Péczely's average field (*Péczely, 1957, Péczely, 1961*) system developed for macrosynoptic situations over the Carpathian basin. (This coding system separates 13 different situations.) According to our expectations there is significant difference between the accuracies of the expansions carried out by Péczely's and the Hess—Brezowsky's systems at daily fields reproduced by expansional coefficients. The Hess—Brezowsky's expansion representated by 29 coefficients is definitely more exact than the expansion carried out in accordance with the Péczely's system which was described by 13 coefficients. This can be explained by the more general and more differentiated character of the Hess—Brezowsky's system, furthermore with the fact the Péczely's system relates mainly to Hungary and our investigations were extended to the whole Atlantic-European area. The method presented in this paper does not use the expansion by a trigonometric function system (as for e. g. the Fourier's expansion system), nor by the eigen-system of the covariance matrix (as Karhunen—Loeve's natural orthogonal expansion), but it applies the expansion of the meteorological average fields of Hess—Brezowsky's macrosynoptic types. With the natural orthogonal expansion it came out that it is difficult to interpretate the obtained coefficients physically, and the practical solution of the eigenvalue problem is difficult even applying the modern methods of computer techniques. Using the expansion of meteorological average fields of Hess—Brezowsky's macrosynoptic types we do not have to face such difficulties because the function-system by which the expansion is carried out is given in advance.

The expansion and reproduction of the fields are being done by a sequence of programs. These programs were run partly on a Siemens type computer with operational system BS/1000—2000, and partly on IBM 370 in FORTRAN IV.

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CLIMATIC RESEARCH AND THE WEATHER-FORECASTS

by

G. Koppány

Éghajlatkutatás és az időjárás-előrejelzés. Az időjárást illető bizonytalanság meghatározható a Shannon-entrópia segítségével, ha ismeretesek az egyes időjárási jelenségek éghajlati valószínűségei. A dolgozat példákat mutat be a prognózis előtti és a prognózis utáni bizonytalanság kiszámítására.

The uncertainty about the weather is defined by means of Shannon-entropy when the climatological probabilities of weather phenomena are available. The paper presents examples for the calculation of the uncertainties before and after the weather-forecasts.

The purpose of classical climatology was the statistical analysis of the several decade long measured data sets of a given geographical point. Statistical characteristics have been set up in order to characterize the climate of the given place, such as: 1) averages of many years or normal values, 2) the relative frequencies of the deviations from normal values, 3) the average value or the standard deviation of the deviations from the normal values (anomalies), 4) the size of absolute amplitudes (records), 5) the annual variation of the normal values of climatological parameters.

The above characteristics have proved to be very useful in the following fields of practical usage: the acclimatization of agri-cultures, the planning of water-economy, the planting of wind or water power stations and so on. The growing lenght of data sets and the spreading of the non-classical means of climatological research (dendrochronology, pollen-analysis and so on) have made the examination of the fluctuation of weather important.

The interest of meteorologists has turned from climate-research to weather-forecast since the 1930-ies. It is not our aim to deal here with the historical reasons of this fact here. However, we are sorry to say that because of the separation of climatology and synoptic meteorology, a really deep connection could not have been created between the two major territories of meteorology. In our opinion synoptic meteorology, which is dealing with weather-forecast could profit much more from the climatological characteristics than it practically does.

In the 1950-ies *G. Péczely* was the first among the Hungarian researchers who was eager to build a bridge between climatology and synoptic meteorology (1957). He found the base of *synoptic climatological* research by elaborating the 13 Hungary oriented large-scale weather situations. Synoptic climatology is a special adaptation of the more generally so-called *conditional climatology*. The essence of conditional climatology is that we examine a clima-factor (e. g. temperature) in the condition of another (wind direction), because we suppose that there is a statistical connnection between the two factors (*Fig. 1*).

We get a new way of approach of the prognostical importance of the results of weather-forecast if it is defined on the basis of information theory:

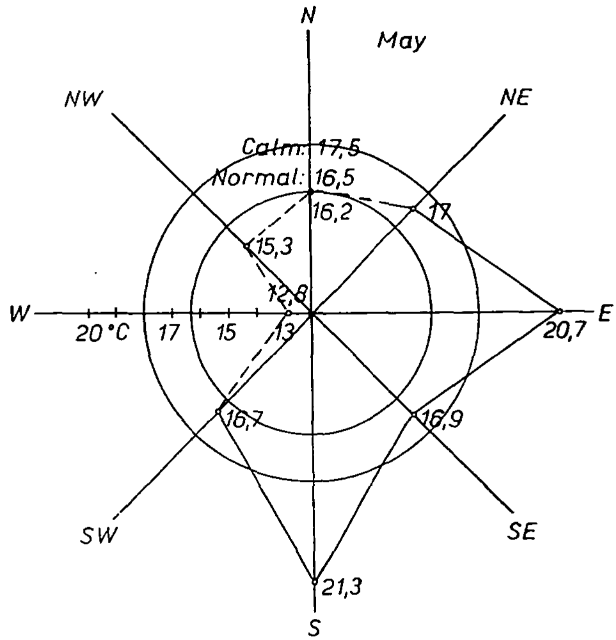

Fig. 1. The daily mean temperatures in Budapest in May as functions of wind direction and wind speed (after A. Réthly). Legend: the temperature is measured by distance from the origo; the monthly average and mean value for calm days are denoted with concentric circles, the expected temperatures for the 8 wind directions are also denoted.

Only that forecast is considered real which aims to reduce some kind of uncertainty. In *contrary* to this definition here are some examples of wrong forecast:
1. The July mean temperature next year in Hungary will be higher than the January mean temperature, 2. the number of sunny hours will be higher in the summer months than in the period from November to January, 3. there won't be significant precipitation in Israel next summer.

There is no need to prove that the above statements are highly certain on the basis of our knowledge (The coldest July in Budapest was in 1913 with the average of 18.4 °C and the mildest January was in 1983, with an average of 5.1 °C. The number of sunny hours in our country is much higher in summer than between November and January, which is due partly to astronomical reasons and partly to the yearly variation of clouds. In Israel there are precipitation data from Jerusalem back to 1861, and during the 120 years they never got a precipitation more than 1 mm in the summer time.) That's why in our examples the predictions to the future can't be considered as forecasts, namely they lack the obligatory uncertainty.

But we may put such a question concerning the future where there is a smaller or bigger uncertainty connected with the correct answer. Let our question be: what will be the mean monthly temperature in Budapest next December?

The answers to the question are determined by the collected clima data lines of Budapest back to 1780. According to this there were as low as -10 °C (1879) and as high as $+5.6$ °C (1826) mean temperatures in December. During the past 204 years the amplitude of monthly temperature comes up to almost 16 degrees. The uncertainty connected with our problem depends on the probability of answers on the bases of climatology.

In our table there is a survey of the relative frequency of monthly mean temperatures in Budapest in 1780—1983 in 16 one-degree intervalls.

Table 1

The relative frequency of monthly mean temperatures in December in Budapest between 1780—1983

−10 −9	−9 −8	−8 −7	−7 −6	−6 −5	−5 −4	−4 −3	−3 −2	centigrades
0.5	0.5	—	1.0	0.5	2.9	3.9	6.4	%
−2 −1	−1 0	0 1	1 2	2 3	3 4	4 5	5 6	centigrades
7.4	9.3	19.6	16.2	12.2	12.2	5.0	2.4	%

The *Shannon-entropy* should be used to measure uncertainty. Let Q be the well-defined question, to which we expect an answer from the forecast. A question is called well-defined if the place the time and the needed information are given. All the information we have concerning the Q question (the climatological knowledge) should be signed X. Let's suppose that „m" is the number of answers that can be given to the question according to our climatological knowledge, and the climatological probabilities of an answer (relative frequencies) $p_1, p_2, \dots p_m$ are known. We are uncertain about which of the m possibilities will be realized.

The value of uncertainty can be estimated in the following way using the Shannon-entropy:

$$S(Q/X) = \sum_{i=1}^{m} p_i \cdot \mathrm{ld}\; 1/p_i, \quad \text{(bit)} \tag{1}$$

where S stands for the Shannon-entropy concerning the well-defined Q question, of which we have X information, p_i stands for the possibility of the i-th answer that can be given to the question Q, while ld $1/p_i$ stand for the logarithm to the base 2 of this probability with a minus sign. Using logarithm to the base 10, equation (1) can be written in the form:

$$S(Q/X) = 1/\log 2 \sum_{i=1}^{m} p_i \cdot \log 1/p_i \quad \text{(bit)}. \tag{2}$$

We can interpolate from our table that 50% of the December mean temperatures happened to be lower than +0.4 °C and 50% higher than that. If we expect from our forecast the information whether the monthly mean temperature is below or above the median (+0.4 °C) then according to formulae (1) or (2) the uncertainty is one bit. If we expect from our forecast however to tell the monthly mean temperature in one-degree interval, then putting the relative frequencies in our table into formula (1) the uncertainty can be exactly calculated: *3,3278 bit.*

We can avoid the long-lasting calculation if we divide the weather-data sets into 4 or 8 categories with equal probabilities using the quartiles or octiles. In this case the uncertainly will be 2 or 3 bits. When trying to forecast the amount of precipitation, three categories with equal probabilities, the so-called tertiles, are used very often. In this case the uncertainty before the forecast according to equasion (1) is *1,5849 bit*.

Thus uncertainty to be decreased by the forecast depends on one hand on our expectations about the forecast, in our example on the broadness of the intervalls in which we want to foretell the temperature. The narrower the intervalls are in which we want to forecast the bigger the uncertainty is. On the other hand the uncertainty depends on the climatological probabilities. It is evident that the uncertainty increases if the climatological probabilities of the answers given to the question Q are almost equal.

The uncertainty is almost maximal when in the case of m possible answers:

$$p_1 = p_2 = \ldots = p_m = 1/m.$$

We know from experience that the accuracy of weather-forecasts turns out to be limited. In other words: the forecasts are approximations of reality with some error. The relative frequencies of errors can be determined by the verification of a comperatively high number of forecast.

The information gain obtained from the forecast reports is defined as the difference between two entropy values: one of them reflecting our knowledge before the forecast (X), the other one (X') is that after the forecast, and is obtained by the verification of a number of forecasts so that we determine the relative frequency of the errors of prognosis. The information gain is:

$$L = S - S'. \tag{3}$$

Where S and S' are the uncertainties before and after the forecast, respectively.

The more we can reduce the uncertainty after the forecast (S'), the bigger the information gain is. In order to determine S' we use the probabilities (p_i') of the errors of the forecasts.

It is evident that the smaller is the standard deviation of errors the bigger is the information gain and the smaller the value of S'. This is also true if there is a systematical error in the forecast but we know this error from experience. In this case we can correct the forecasts according to our knowledge of systematical errors (*Koppány, G*, 1975.).

On the contrary if the standard deviation of the errors of the forecasts is bigger than that of the climatological data, the uncertainty increases after the forecast and the information gain is negative.

Let us have a simple example for the sake of better understanding.

Let our task be the forecast of temperature in five equally probable categories. The limits of categories are determined in this case by the quinteles. The uncertainty before the forecast is:

$$S = 5 \cdot 0{,}2 \cdot \mathrm{ld}\, 5 = 2{,}322 \quad \text{bit}.$$

Let us have an enough number of verified forecasts and let us suppose that the probability of the correct forecasts: $p_k' = 0.5$, and that of the errors referring to two categories: $p_k' \pm 2 = 0$, and that of the errors referring to one category is $p_k' \pm 1 = 0.25$. In this case:

$$S' = 0.5\, \mathrm{ld}\, 2 + 2 \cdot 0.25 \cdot \mathrm{ld}\, 4 = 1.5 \quad \text{bit}$$

and the information gain is:

$$I = S - S' = 2.322 - 1.5 = 0.822 \ \text{bit}.$$

Informative results are obtained by the following modifications. Let $p'_{k+1}=0.6$, $p'_k=0.4$ and $p'_{k+2}=p'_{k-1}=0$. So the probability of the correct forecast is 40%, that of the false estimation of plus one category is 60% and the probability of all the other errors is 0. In this case uncertainty after the forecast is:

$$S' = 0.6 \cdot \mathrm{ld}\ 1/0.6 + 0.4 \cdot \mathrm{ld}\ 1/0.4 = 0.9709 \text{ bit.}$$

The information gain is:

$$I = S - S' = 2.322 - 0.9709 = 1.3511 \text{ bit.}$$

In the latter case there is a systematical error in our forecasts: in 60% of the cases next higher category was realized instead of the expected one. The uncertainty of the realibility of our forecast can be increased by correcting with this systematical error. The information gain has increased as compared to the previous example, because the standard deviation of errors has decreased.

Finally, let us consider in brief the importance of the synoptic climatology as reflected in the information theoretical adaptation of forecast. According to the long data sets from Budapest the absolute amplitude of the January daily mean temperature is 32 °C and 19 °C, respectively. The standard deviation of meteorological data is comparatively high. The standard deviation of the daily mean temperatures categorized by the macrosynoptical categories decreases. (*Péczely, Gy.*, 1961.) So if the forecast of the atmospherical pressure, based on the service of the Meteorological Regional Centers are at our disposal for the next few days then the forecast field can be identified as a macrosynoptical type. Since the standard deviation of the temperatures belonging to a macrosynoptical type is smaller than that of the general climatological data the uncertainty connected with the expected daily mean temperature decreases. This is naturally true not only in the case of temperature but also for the other meteorological parameters.

Attention should be paid to a quantitative study in which from the data sets of certain meteorological parameters (wind direction, wind speed, clouds, rain, etc.) the relative frequency of these would be provided in the given scale and also for the categorized data sets according to Péczely's types. Having all these data it would be possible to determine the uncertainty connected with the expected figure of the individual meteorological parameters and also the decrease of this uncertainty supposing the knowledge of Péczely's macrosynoptical types for the next few days.

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SUPPLEMENTS TO THE CATEGORIES OF CONTEMPORANEOUS TEMPERATURE AND PRECIPITATION ANOMALIES IN HUNGARY AND TO THEIR STATISTIC ANALYSIS

by

L. Makra

Adalékok egyidejű hőmérséklet- és csapadékanomáliák magyarországi kategóriáihoz és azok statisztikai elemzéséhez. Jelen tanulmány célja Magyarország területére egyidejű hőmérséklet- és csapadékanomáliák kategóriáinak megalkotása, s azok egymáshoz kapcsolódása mértékének statisztikai elemzése.

Az egyes kategóriák havi gyakorisági értékei eltérőknek mutatkoztak; a kategóriák ismétlődési tartamának gyakorisági eloszlása, csakúgy mint az ismétlődések átlagos hosszúsága egymástól független események következményeiként adódtak.

The aim of present study is creating weather categories on the basis of contemporaneous temperature and precipitation anomalies occurring in Hungary, and a statistic analysis of their rate of connection.

The monthly frequency of the single categories seemed to be different; the frequency distribution of the recurrence period of the categories as well as the average length of the recurrences followed as the consequences of unrelated events.

In present study data for processing was supplied by the areal average values of yearly and monthly precipitation at ten meteorological stations in Hungary (Szombathely, Keszthely, Magyaróvár, Pécs, Kalocsa, Budapest, Szeged, Eger, Túrkeve, Nyíregyháza, Table 1) [1] and territorial averages of monthly and yearly mean temperature time series observed at six stations (Keszthely, Magyaróvár, Pécs, Budapest, Szeged, Debrecen, Table 2). The time series refer to 110 years between 1871 and 1980, containing in this way data from 1320 months.

Geographical coordinates (φ, λ) and heights above sea level (h) of observing stations are as follows:

		(φ)	(λ)	(h)
1.	Szombathely	16°36′	47°15′	215
2.	Keszthely	17°14′	46°45′	128
3.	Magyaróvár	17°16′	47°53′	122
4.	Pécs	18°12′	46°04′	123
5.	Kalocsa	18°59′	46°32′	96
6.	Budapest	19°02′	47°31′	118
7.	Szeged	20°09′	46°15′	74
8.	Eger	20°23′	47°53′	173
9.	Turkeve	20°45′	47°07′	88
10.	Debrecen	21°37′	47°33′	123
11.	Nyíregyháza	21°41′	47°59′	105

Deviations from the average, that is to say anomalies were attached to each of the time series, i. e. wet and dry, warm and cold periods were discerned according to deviations from the average. Considering the number of alternative elementary

Table 1

(Statistical characteristics of regional averages made from monthly and annual precipitation amounts (mean ($\bar{x}$), standard deviation (σ)), Hungary, 1871—1980.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	*Year*
$\bar{x}$	33,691	32,136	37,591	51,409	66,027	74,855	65,800	61,046	49,700	54,173	53,273	44,064	623,927
σ	16,015	19,279	19,691	23,673	26,757	25,934	27,429	26,873	24,896	32,856	29,090	20,853	89,889

Table 2

Statistical characteristics of regional averages made from monthly and annual mean temperatures (mean ($\bar{x}$), standard deviation (σ)), Hungary, 1871—1980.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	*Year*
$\bar{x}$	−1,579	0,450	5,359	10,821	15,730	19,183	21,173	20,408	16,447	10,960	5,044	0,536	10,358
σ	2,854	2,837	2,191	1.662	1,663	1,335	1,259	1,279	1,526	1,721	2,053	2,483	0,693

Table 3

Anomaly Categories (1871—1980)
wet-warm (1), wet-cold (2), dry-warm (3), dry-cold (4)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	*Year*
1871	2	4	1	4	4	2	3	3	3	2	2	4	4
1872	3	3	1	3	3	2	3	2	1	1	1	3	1
1873	1	1	3	2	2	2	3	3	2	3	3	4	3
1874	4	4	4	3	2	1	3	2	3	3	4	1	4
1875	3	4	4	4	3	1	1	3	4	2	2	4	4
1876	4	2	1	3	2	1	4	3	2	3	4	1	2
1877	3	1	2	2	2	3	2	3	2	4	3	2	4
1878	2	3	2	3	3	3	2	1	1	1	1	2	1
1879	2	1	4	2	2	1	2	3	1	2	4	4	2
1880	4	4	4	3	2	4	3	2	1	1	1	3	2
1881	2	4	2	2	2	2	3	1	2	2	4	4	2
1882	3	3	3	3	4	4	1	2	1	1	1	1	1
1883	1	3	2	4	4	1	1	4	2	1	2	4	2
1884	3	3	3	2	3	2	1	2	4	2	4	1	4
1885	4	3	3	3	2	3	1	2	3	1	3	4	3
1886	1	4	4	1	3	2	4	3	3	1	3	1	3
1887	4	4	2	4	2	4	3	4	3	2	1	2	4
1888	4	2	4	2	3	1	2	2	3	2	4	4	4
1889	4	2	2	2	3	3	1	4	2	1	4	4	2
1890	1	4	3	1	3	4	3	3	4	2	1	4	4
1891	2	4	2	2	3	2	2	2	3	3	2	3	2
1892	2	1	2	1	1	1	4	3	1	1	4	4	2
1893	2	1	4	4	4	2	2	4	4	3	2	3	2
1894	4	3	3	1	1	4	3	3	4	1	4	4	3
1895	2	2	2	2	2	2	1	2	3	2	3	2	2
1896	4	4	3	2	2	1	1	2	1	3	2	3	2
1897	1	3	1	2	2	1	2	1	1	2	4	4	2
1898	3	3	1	1	1	2	2	3	4	1	3	3	3
1899	1	3	4	3	2	4	2	4	2	4	3	2	2
1900	1	1	2	4	2	1	1	2	3	1	1	3	1
1901	4	4	1	1	3	3	1	2	2	3	4	3	2
1902	3	1	2	4	2	2	2	3	4	2	4	4	2
1903	4	3	3	2	4	2	2	4	1	3	1	1	1
1904	4	1	1	3	4	3	3	3	2	1	4	3	3
1905	4	3	3	2	2	1	3	3	1	2	1	3	1
1906	1	1	1	3	3	2	2	4	2	4	3	2	1
1907	2	4	4	2	3	3	2	4	4	3	4	1	4
1908	4	1	2	2	3	3	4	2	4	4	4	4	4
1909	4	4	2	3	2	4	4	1	1	3	4	1	4
1910	1	1	3	2	2	1	4	4	2	3	2	3	1
1911	3	4	3	4	2	4	3	3	3	1	3	3	3
1912	2	1	1	2	2	3	4	2	2	4	4	3	2
1913	4	4	3	4	2	4	2	2	2	3	3	3	2
1914	4	4	1	3	2	2	2	4	2	4	4	1	2
1915	1	1	2	4	3	1	2	2	2	2	2	1	2
1916	3	1	1	2	3	4	4	4	2	4	3	1	1
1917	1	4	2	4	3	3	3	3	3	3	3	2	4
1918	3	3	3	3	3	4	4	2	1	1	2	1	3
1919	1	1	1	2	2	4	2	4	3	4	2	1	2
1920	1	3	3	3	3	2	1	4	3	4	4	1	3
1921	3	1	3	4	3	4	3	1	4	3	2	4	3
1922	2	4	1	2	3	3	4	4	2	2	4	3	2
1923	3	1	1	2	3	4	3	3	3	1	1	1	3
1924	4	2	2	2	1	1	4	2	3	3	4	4	4
1925	3	1	4	3	1	2	2	2	2	3	1	4	1
1926	1	3	4	3	4	2	2	4	3	1	3	3	1
1927	1	4	1	4	2	3	3	1	1	4	3	4	1

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	*Year*
1928	3	3	4	3	2	2	3	3	1	4	1	4	3
1929	2	4	4	2	1	4	3	3	3	1	1	3	4
1930	3	1	1	1	4	3	3	2	1	1	3	1	1
1931	1	1	2	2	3	3	3	2	2	4	4	4	4
1932	4	4	2	4	1	4	3	3	3	1	4	4	4
1933	4	3	1	4	2	2	3	1	4	1	1	2	2
1934	4	3	3	3	3	2	3	3	1	3	1	3	3
1935	4	2	4	2	4	3	3	1	3	3	3	1	3
1936	1	1	3	3	1	4	1	4	2	2	4	3	1
1937	2	3	1	2	3	1	2	2	1	3	1	1	1
1938	1	3	3	4	2	3	1	1	4	3	3	2	3
1939	3	3	2	3	2	1	3	1	2	2	1	4	1
1940	2	2	4	3	2	2	2	2	2	2	3	4	2
1941	2	1	1	2	4	4	2	2	4	2	2	3	2
1942	2	2	4	2	1	3	4	3	3	3	4	3	4
1943	4	1	3	3	4	2	1	3	3	3	2	2	3
1944	3	2	2	3	2	2	2	3	3	1	1	4	1
1945	2	3	3	3	3	3	3	3	1	4	1	3	3
1946	4	1	3	3	1	1	3	3	3	3	1	2	3
1947	2	2	1	3	3	3	3	3	3	4	3	1	3
1948	1	1	3	3	3	2	2	3	3	3	4	4	3
1949	3	3	4	3	1	4	2	2	3	3	1	3	3
1950	2	3	3	1	3	3	3	3	1	3	1	1	3
1951	3	1	1	3	1	1	1	3	1	4	3	3	1
1952	1	1	2	3	4	3	3	3	2	2	2	1	1
1953	1	3	3	1	2	1	1	4	3	3	4	4	3
1954	2	4	1	2	2	1	2	3	3	4	4	1	2
1955	1	1	4	4	4	4	2	2	3	2	3	1	2
1956	3	2	4	4	2	2	3	3	3	4	2	4	4
1957	4	1	3	3	2	3	1	4	4	4	3	3	3
1958	1	1	2	4	3	2	3	3	3	3	3	1	3
1959	1	4	3	1	3	2	1	4	4	4	3	1	3
1960	2	2	3	3	4	3	2	4	2	1	1	1	1
1961	4	3	3	1	4	3	4	4	3	3	1	4	3
1962	3	4	2	3	4	4	2	3	4	3	1	4	4
1963	2	2	2	3	3	3	3	1	1	4	3	2	4
1964	4	4	2	3	4	1	4	4	2	2	3	2	2
1965	1	4	1	2	2	2	2	2	3	4	2	1	2
1966	2	1	3	1	4	2	2	2	4	3	2	1	1
1967	2	3	3	2	1	4	3	3	1	3	3	4	3
1968	4	3	3	3	3	3	4	2	2	3	1	4	3
1969	4	2	4	4	3	2	4	2	3	3	1	1	2
1970	2	2	2	2	4	2	2	2	4	4	3	1	2
1971	1	3	4	3	3	4	4	3	4	4	2	3	3
1972	3	3	3	1	2	3	1	2	4	4	1	3	1
1973	3	3	3	2	3	2	4	3	3	4	4	4	4
1974	1	1	3	4	2	2	4	1	4	2	3	3	1
1975	3	3	1	4	1	2	2	2	3	4	4	3	3
1976	1	4	4	3	4	4	3	4	2	3	3	1	4
1977	1	1	1	4	3	3	4	4	4	3	1	4	3
1978	3	4	3	4	2	2	2	4	4	4	4	1	4
1979	2	1	1	4	3	1	4	4	4	4	1	1	3
1980	4	3	4	2	4	2	2	4	4	2	2	4	2

events belonging to two time arrays four categories were established for different events: wet-warm (1), wet-cold (2), dry-warm (3) and dry-cold (4) *(Table 3).*

The monthly, yearly (110—110 basic periods) number of repetitions and frequency values of the individual anomaly categories were determined where observations were considered in a continous process starting with the first observation

(1320 basic periods). One repetition means an uninterrupted series of a given weather type occurring during successive basic periods (a month or a year). The number of repetitions and frequency of the individual categories do not contain the first and last repetition of a given basic period, the duration of their series being unknown.

Data thus obtained was considered from two main angles. It was examined if empiric frequency distribution of the repetition of the individual anomaly categories correspond to certain theoretic assumptions, as well as the monthly average durations of repetitions were determined and statistically evaluated.

Our test results emerging from mentioned observation material are as follows: According to basic probabilities of individual anomaly categories *(Table 4)* the recurrence of the warm-dry, (3), anomaly category is the most probable not only during five months (March, April, August, September, October) but considering the yearly time-series and the 1320 months between 1871 and 1980 as well. The wet-cold (2) anomaly category is most common in May, June, July.

Correlating territorial average values of monthly precipitations and mean temperatures for the months of the summer half year (April, May, July, August, September) a statistically realistic contrasting connection can be observed. This is an unambigous consequence of the preponderance of the wet-cold (2) and dry-warm (3) anomaly categories. In the winter half year this connection becomes blurred.

The probability of any anomaly category repeating itself during the month following a given basic period shows a characteristic yearly course. Its value appears to be the highest from January to February, this is mainly a consequence of the greater frequency of wet-warm anomaly category (1), and from February to March as well as from July to August, in latter cases it is mainly a product of the frequent repetition of dry-warm (3) anomaly category. For the months of the intermediate seasons this repetition occurs with a lesser frequency so its probability is lower, too.

Analysing monthly empiric frequency values of the individual anomaly categories an increase can be observed in the repetition periods of wet-cold (2) and dry-warm (3) categories, first of all during the summer half year. To decide if this is a systematic occurence or only a random succession of events, the frequency distribution of repetition periods obtained from independent events was determined *(Table 5)*. In the next step we considered the possibility with the help of χ^2-proof if these two distributions could be regarded as a distribution of specimens taken from a basic agglomeration with identical distribution. According to obtained results the probability of fullfilling hypothesis zero is always at least 10% with the exception of one which means that the specimens origin from a basic agglomeration of identical distribution. Occasionally even better than 90% approaches were obtained. Only calculations referring to the specimen consisting of 1320 months (from 1871 to 1980 regarded as a whole) gave a little higher result than 2% for the fullfillment of hypothesis zero. It can be stated that the empiric frequency distribution of the duration of repetitions — with above mentioned exceptions — is not inconsistent with the independency hypothesis.

After this frequency distribution of repetition periods was determined satisfying the conditions of homogenous Markov-chains *(Table 3)*. As a result of χ^2-proof it was obtained that the previously supposed and the real empiric frequency distribution of repetitive periods can be regarded as specimens originating from a basic agglomeration of identical distribution with a great probability. Considering that on most occasions the independence hypothesis gave closer relation than the conditions of homogenous Markov-chains, the empiric frequency distribution of repetitive pe-

Table 4

The p_i basic probabilities of the single i anomaly category, ($i=1, 2, 3, 4$), 1871—1980

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	*Year*	*all the months*
p_1	0,269	0,306	0,224	0,120	0,130	0,208	0,181	0,115	0,210	0,213	0,278	0,306	0,213	0,209
p_2	0,232	0,139	0,234	0,306	0,352	0,302	0,324	0,317	0,257	0,194	0,157	0,120	0,278	0,248
p_3	0,232	0,296	0,336	0,352	0,343	0,264	0,395	0,356	0,333	0,278	0,269	0,306	0,304	0,304
p_4	0,269	0,259	0,206	0,222	0,176	0,226	0,200	0,212	0,200	0,259	0,287	0,306	0,204	0,240

Table 5

Frequency distribution of recurrences of i weather type (i = 1, 2, 3, 4) in case of independence (a), *in real case* (b) *and in case of homogeneous Markov-chains* (c), *month*

January

	1	2	3	4
1a:	16	4	1	—
1b:	17	6	—	—
1c:	18	4	1	—
2a:	15	3	1	—
2b:	15	2	2	—
2c:	14	3	1	—
3a:	15	3	1	—
3b:	23	1	—	—
3c:	23	1	—	—
4a:	16	4	1	—
4b:	13	3	2	1
4c:	12	4	1	1

February

	1	2	3	4
1a:	16	5	1	—
1b:	23	5	—	—
1c:	24	4	1	—
2a:	11	2	—	—
2b:	11	2	—	—
2c:	11	2	—	—
3a:	16	5	1	—
3b:	13	3	3	1
3c:	13	5	2	1
4a:	15	4	1	—
4b:	16	6	—	—
4c:	17	4	1	—

March

	1	2	3	4
1a:	14	3	1	—
1b:	20	2	—	—
1c:	20	2	—	—
2a:	15	3	1	—
2b:	14	4	1	—
2c:	14	3	1	—
3a:	16	5	2	1
3b:	19	4	3	—
3c:	19	5	1	—
4a:	14	3	1	—
4b:	12	5	—	—
4c:	13	3	1	—

April

	1	2	3	4
1a:	10	1	—	—
1b:	13	—	—	—
1c:	13	—	—	—
2a:	16	5	1	—
2b:	21	3	2	—
2c:	20	4	1	—

April

	1	2	3	4
3a:	16	6	2	1
3b:	22	3	1	—
3c:	19	6	2	—
4a:	15	3	1	—
4b:	15	3	1	—
4c:	15	3	1	—

3b: recurrence of 7 months on one occasion

May

1a:	11	1	—	—
1b:	12	1	—	—
1c:	12	1	—	—
2a:	16	6	2	1
2b:	11	6	3	—
2c:	12	5	2	1
3a:	16	5	2	1
3b:	16	3	1	3
3c:	14	5	2	1
4a:	13	2	—	—
4b:	12	2	1	—
4c:	12	2	1	—

2b: recurrence of 6 months on one occasion

June

1a:	14	3	1	—
1b:	15	2	1	—
1c:	15	3	—	—
2a:	16	5	1	—
2b:	15	7	1	—
2c:	17	5	1	—
3a:	15	4	1	—
3b:	20	4	1	—
3c:	21	3	—	—
4a:	14	3	1	—
4b:	22	1	—	—
4c:	22	1	—	—

July

1a:	13	2	—	—
1b:	11	2	—	1
1c:	10	3	1	—
2a:	16	5	2	1
2b:	11	7	3	—
2c:	13	5	2	1
3a:	15	5	1	—
3b:	15	2	1	—
3c:	12	5	2	1
4a:	13	3	1	—
4b:	14	2	1	—
4c:	14	3	—	—

3b: recurrence of 9 months on one occasion

August

	1	2	3	4
1a:	9	1	—	—
1b:	10	1	—	—
1c:	10	1	—	—
2a:	15	5	2	—
2b:	14	8	1	—
2c:	16	5	1	—
3a:	15	5	2	1
3b:	20	2	2	—
3c:	17	5	2	1
4a:	14	3	1	—
4b:	15	2	1	—
4c:	15	3	—	—

3b: recurrence of 7 months on one occasion

September

1a:	14	3	1	—
1b:	13	3	1	—
1c:	13	3	1	—
2a:	15	4	1	—
2b:	18	2	—	—
2c:	16	4	1	—
3a:	16	5	2	1
3b:	16	2	1	3
3c:	14	5	2	1
4a:	13	3	1	—
4b:	14	2	1	—
4c:	14	3	—	—

2b: recurrence of 5 months on one occasion

October

1a:	14	3	1	—
1b:	15	4	—	—
1c:	16	3	—	—
2a:	14	3	1	—
2b:	16	1	1	—
2c:	15	2	—	—
3a:	16	5	2	1
3b:	13	8	1	1
3c:	15	5	2	1
4a:	15	4	1	—
4b:	16	4	—	1
4c:	16	4	1	—

November

1a:	16	4	1	—
1b:	16	4	2	—
1c:	16	4	1	—
2a:	12	2	—	—
2b:	13	2	—	—
2c:	13	2	—	—
3a:	16	4	1	—
3b:	17	5	1	—
3c:	18	4	1	—

November

	1	2	3	4	5	6
4a:	16	5	1	—		
4b:	20	4	1	—		
4c:	20	4	1	—		

December

1a:	16	5	1	—
1b:	16	4	3	—
1c:	16	5	1	—
2a:	10	1	—	—
2b:	9	2	—	—
2c:	9	1	—	—
3a:	16	4	1	—
3b:	15	5	—	1
3c:	15	4	1	—
4a:	16	5	1	—
4b:	18	6	1	—
4c:	19	5	1	—

Year

1a:	14	3	1	—	—	—
1b:	14	3	1	—	—	—
1c:	14	3	1	—	—	—
2a:	16	4	1	—	—	—
2b:	7	5	3	1	—	—
2c:	9	4	2	1	—	—
3a:	16	5	1	—	—	—
3b:	16	4	1	—	—	1
3c:	15	5	2	1	—	—
4a:	14	3	1	—	—	—
4b:	11	4	1	—	—	—
4c:	12	3	1	—	—	—

month (1871—1980)

1a:	172	36	7	2	—	—
1b:	126	42	16	3	1	—
1c:	129	41	13	4	1	—
2a:	185	46	11	3	1	—
2b:	147	49	16	3	2	2
2c:	147	48	16	5	2	1
3a:	194	59	18	5	2	—
3b:	153	61	18	9	3	1
3c:	153	58	22	9	3	1
4a:	183	44	11	3	1	—
4b:	160	47	10	4	2	1
4c:	159	46	13	4	1	—

3b: recurrence of 7 months on two occasions riods — in according with above mentioned facts — can be regarded as products of independent events.

The relationship between the average actual and independent duration of repetitions was observed, too. According to our calculations there is a minimal probability of the average duration of repetitions being a consequence of independent events considering every anomaly category, that is the months of February, March, April (wet-warm (1) anomaly category), the wet-cold (2) category in yearly sequence as well as a continous process (from 1871 to 1980) consisting of 1320 months. In all of the remaining cases the independency is valid which means that the average duration of repetitions is not contradictory to a random connection of events of the time-sequence (the succession of different types).

During our experiments explanations were found to the following problems: The characteristic climate of Hungary, first of all in summer half-year, is due to monthly basic probabilities of the different weather types; the different monthly frequency of the individual anomaly categories is explained by a correlation of territorial average values of monthly precipitations and mean temperatures and it was understood that the frequency distribution of repetitive periods of the different types can be regarded as products of independent occurences. Similarly, the average duration of repetitions — with the exception of the continously observed time-sequence containing 1320 minths — do not significantly diverge from independent average durations [2].

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THE INFORMATION CONTENT OF THE TEMPERATURE FIELD OF THE NORTHERN HEMISPHERE AND THE MEAN MONTHLY TEMPERATURES AT SZEGED

by

L. Pelle

Az északi félteke információtartalma és a szegedi havi középhőmérséklet. A tanulmány (Szeged és az északi félteke 83 állomása havi középhőmérsékletei 80 éves sorának felhasználásával) megállapitja, hogy bizonyos állomások előző adatainak ismeretében a klimatológiai előrejelzéshez képest csökkenteni lehet a Szegeden várható havi középhőmérséklet bizonytalanságát. Ezt a szegedi havi középhőmérséklet és a megelőző 12 hónapban az északi félteke 83 állomásán megállapított havi hőmérsékleti átlagok kölcsönös információtartalmának kiszámításával éri el.

The study finds out (using the 80-years line of the mean monthly temperatures of Szeged and 83 meteorological stations of the northern hemisphere) that the uncertainly of the mean monthly temperature to be expected at Szeged can be diminished as compared to the meteorological forecast — with knowledge of dates of certain stations relating to the previous period. This is achieved by computing of the reciprocal information contents of the mean monthly temperatures at Szeged and the mean monthly temperatures fixed at the 83 stations of the northern hemisphere over a period of 12 months preceding the months mentioned.

One of the most important targents of meteorology is to forecast the weather. This difficult and ungrateful work is not resolved yet. According to estimations the theoretic limit of expanding numerical forecasts is two-three weeks at the most. The short and middle-term prognostic based upon mathematical and physical calculations are relatively developed which is not so in the case of long-term forecasts where mostly statistical processes are applied. A method introduced below aims at a contribution of grounding long-term forecasts as well. Since the method involves clearly mathematical statistical features its limitations may not be disregarded when evaluating its results. Our method offers a possibility to correct climatological prognostics. A climatologic prognostic can be established in the following form: If the median of mean temperature in Szeged in January is e. g. m: $-1{,}0$ °C then with the help of climatologic data temperatures above and below $-1{,}0$ °C can be calculated with the same probability.

Test method.

The possible values of discrete random variable ξ should be $x_1, x_2, x_3, \ldots, x_n$, its distribution $p_1, p_2, p_3, \ldots, p_n$ where p_i constitutes the probability of supervention of the event x_i. The definition of entropy of ξ signed $H(\xi)$ is the following:

$$H(\xi) = -\sum_{i=1}^{n} p_i \log p_i. \tag{1}$$

This quantity could be understood as a measure of instability of the random variable. The entropy of continuous random variable:

$$H(\xi) = -\int_{-\infty}^{+\infty} f(x) \log f(x)\, dx \tag{2}$$

where $f(x)$ is a function of density ξ. These definitions can be given for multi-dimensional random variables. The next concept appears to be important from a practical point of view because it measures the closeness of the relation of two random variables, the reciprocal information content of two random variables signed as $I(\xi,\eta)$ is as follows:

$$I(\xi, \eta) = H(\xi)+H(\eta)-H(\xi, \eta). \tag{3}$$

In case of independence $I(\xi, \eta)=0$. The maximum of $I(\xi, \eta)$ is the smaller from the two entropies, $\max \big(I(\xi, \eta)\big)=\min \big(H(\xi)\big), \big(H(\eta)\big)$ and this is true if ξ and η are functions of each other, i. e. with the help of one of them the other can be expressed. We are of course more interested in stohastic connections occurring in reality than in extreme cases, the quantity (3) will be used to measure the previous one. In our test the temperature time sequences used as parting data were described with random variables of normal distribution. Consequently, with the help of (2) and (3) the reciprocal information content of two normal random variables can be calculated:

$$I(\xi, \eta) = -\frac{1}{2}\log(1-r^2) \tag{4}$$

where r is the correlation coefficient between normal random variables ξ and η, the demonstration of (4) can be found e. g. in [2]. If ξ and η are uncorrelated then $I(\xi, \eta)=0$ and if $|r|\to 1$ then $I(\xi, \eta)\to\infty$, so if can be stated that $I(\xi, \eta)$ measures the identity of the linear connection of the two probability variables.

As a data basis of this process the monthly mean temperatures of 83 stations over the northern hemisphere were applied with measurements taken between the period starting with 1880 and up to 1960.

The next step was to examine the information offered by the individual temperature fields (northern hemisphere) with regard to the monthly mean temperatures of specified station — Szeged. The reciprocal information content with the previous 12 months of the whole field was calculated for each monthly sequence in Szeged. For example we calculated the reciprocal information content of random variable describing the October temperature sequence in Szeged and that of the random variable describing the September, August, July, ..., October field over the hemisphere. In such way altogether $12\times12=144$ information quantity fields were obtained. Each of them contains 83 information quantity this means altogether 11 952 calculations. A value acceptable on a 5% significance level was regarded as acceptable. (E. g. if $n=80$, $I(\xi, \eta)=0{,}0348$ bit.) As expected the decisive majority of information quantities appeared to be smaller. In each case, however, a number of values presented themselves higher than this. Maximal information quantities are around 0,14—0,15 bit. From the possible 144 information quantity maps the 14 more interesting ones were sketchd (Fig. 1—13). On these maps the fields with significant values were traced with thick lines. The signs "+" and "−" refer to the direction of the connection. On the basis of the maps it can be stated that certain territories have an important role, especially the south east part of North America, central and western part of Europe. Other territories, such as East India, the Persian Gulf, Mandjuria, Korea, Caribbean Islands represent realistic connections only in a few cases. The information quantities may be used for forecasts with two categories because proportionately with the obtained information the vagueness of forecast diminishes as well. Since 1 bit information is needed to a prognostic with two categories which undoubtedly comes true the maximal 0,15 bit calculated information quantity disallows this possibility, on the other hand, a better solution was found than the

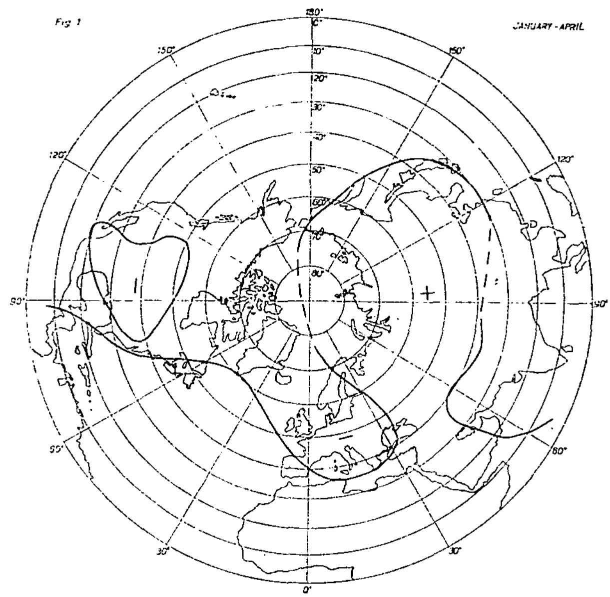

Fig. 1. The regions of the northern hemisphere at which the January mean monthly temperature has an information content relating to the April mean temperature at Szeged

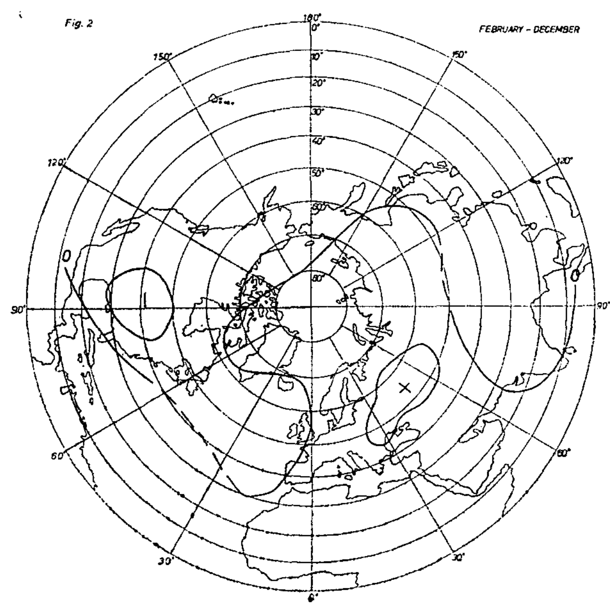

Fig. 2. The regions of the northern hemisphere at which February mean monthly temperature has an information content relating to the December mean temperature at Szeged

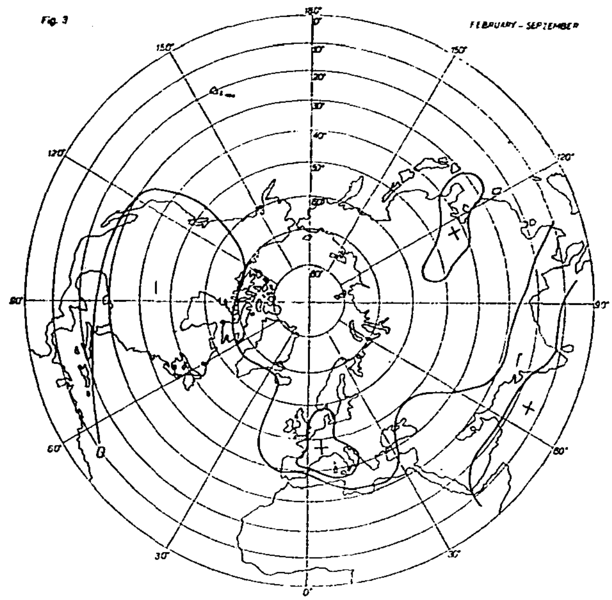

Fig. 3. The regions of the northern hemisphere at which the February mean monthly temperature has an information content relating to the September mean temperature at Szeged

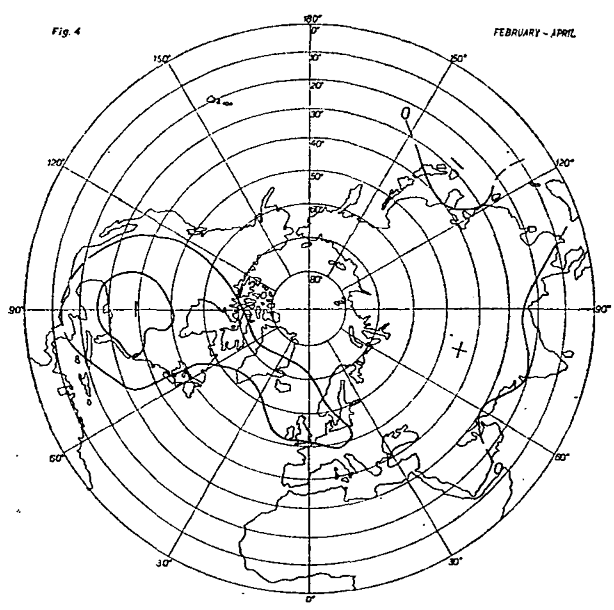

Fig. 4. The regions of the northern hemisphere at which the February mean monthly temperature has an information content relating to the April mean temperature at Szeged

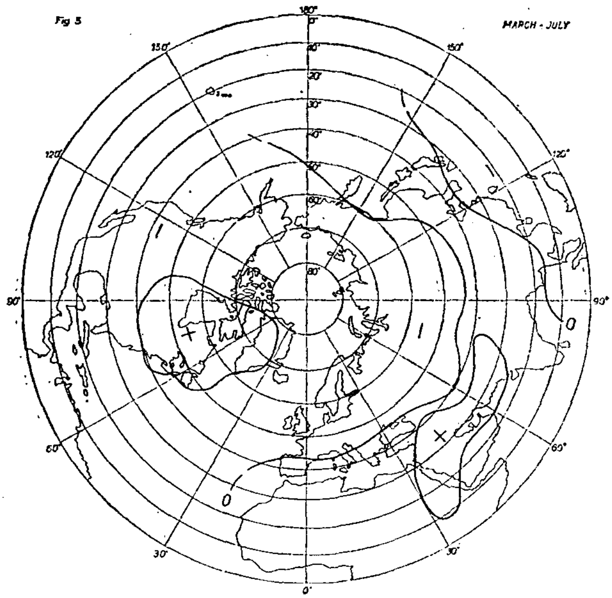

Fig. 5. The regions of the northern hemisphere at which the March mean monthly temperature has an information content relating to the July mean temperature at Szeged

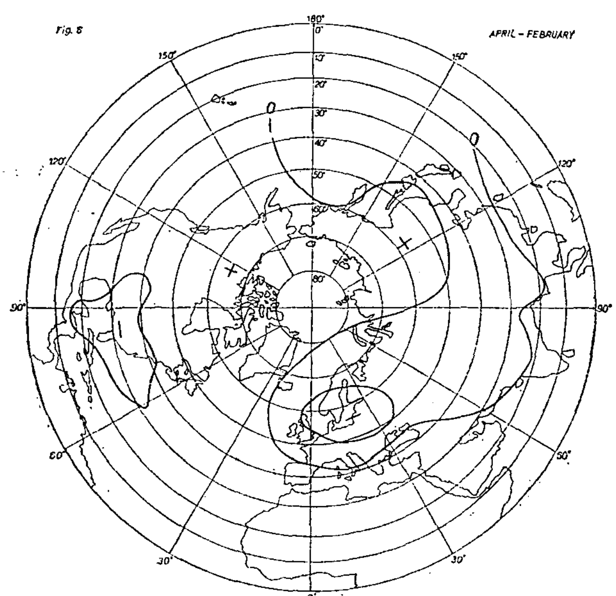

Fig. 6. The regions of the northern hemisphere at which the April mean monthly temperature has an information content relating to the February mean temperature at Szeged

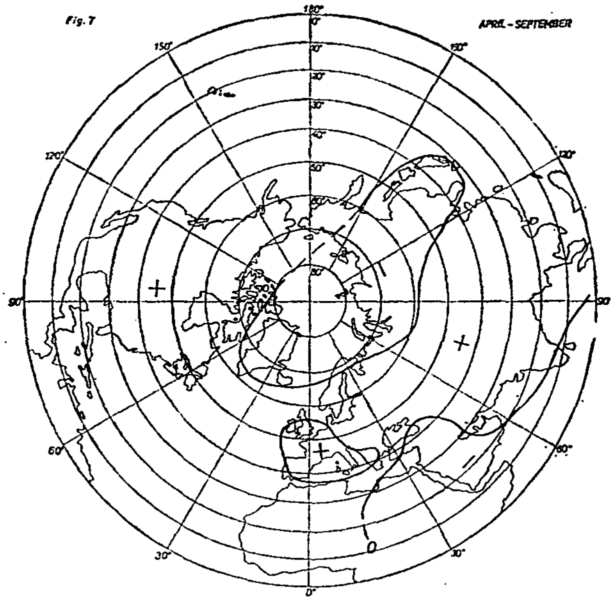

Fig. 7. The regions of he nor hern hemisphere at which he April mean monthly temperature has an information content relating to the September mean temperature at Szeged

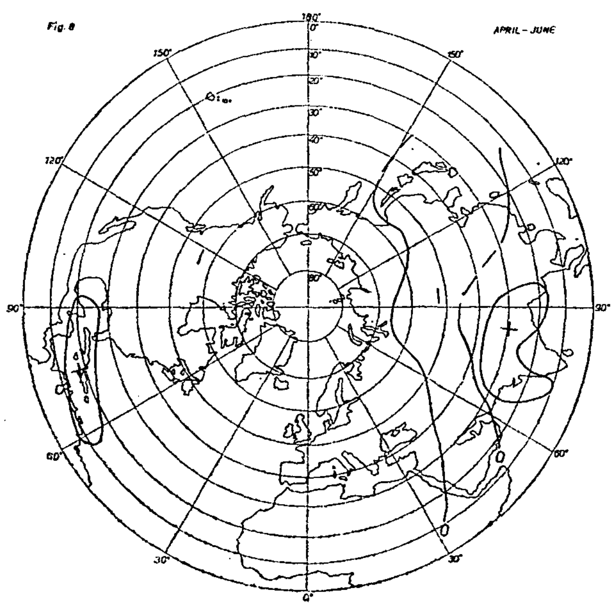

Fig. 8. The regions of the northern hemisphere at which the April mean monthly temperature has an information content relating to the June mean temperature at Szeged

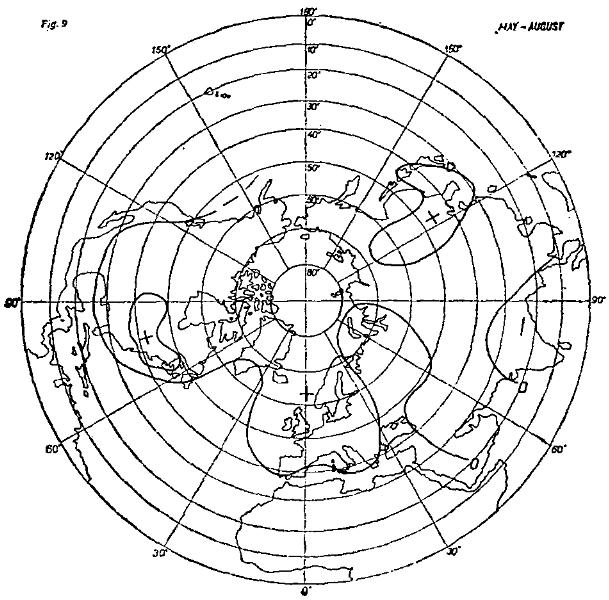

Fig. 9. The regions of the northern hemisphere at which the May mean monthly temperature has an information content relating to the August mean temperature at Szeged

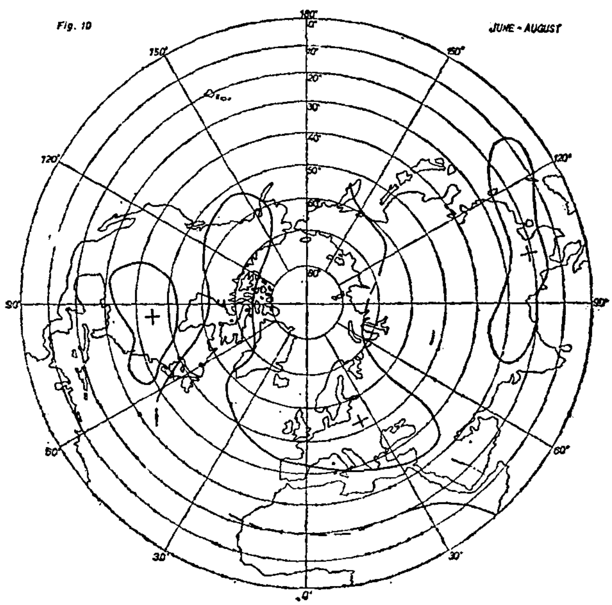

Fig. 10. The regions of the northern hemisphere at which the June mean monthly temperature has an information content relating to the August mean temperature at Szeged

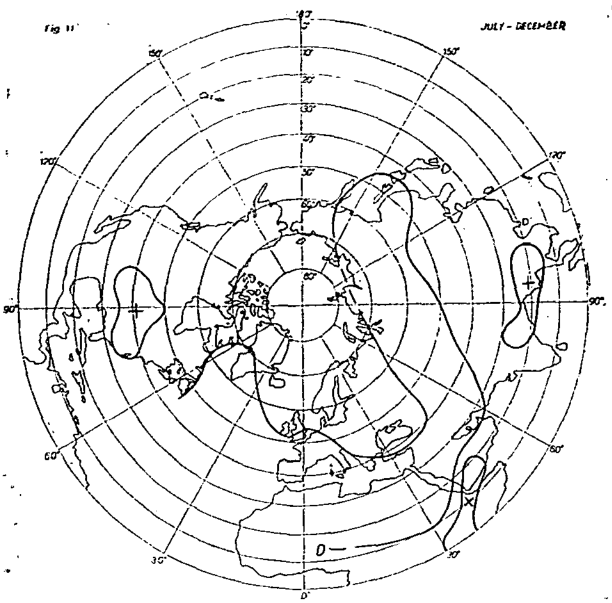

Fig. 11. The regions of the northern hemisphere at which the July mean monthly temperature has an information content relating to the December mean temperature at Szeged

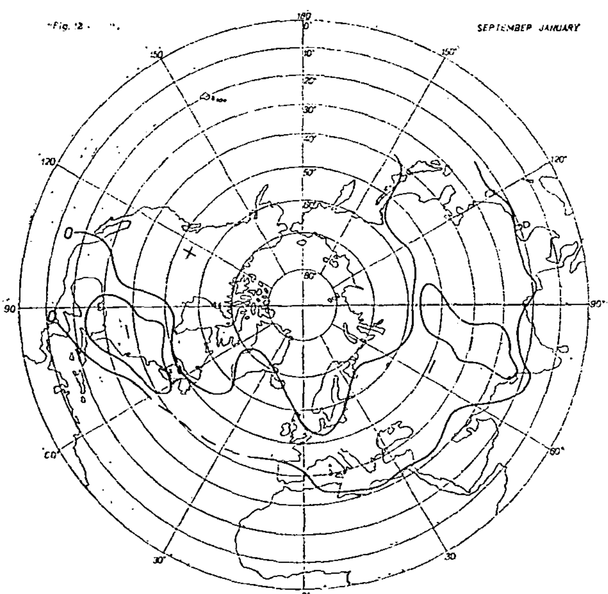

Fig. 12. The regions of the northern hemisphere at which the September mean monthly temperature has an information content relating to the January mean temperature at Szeged

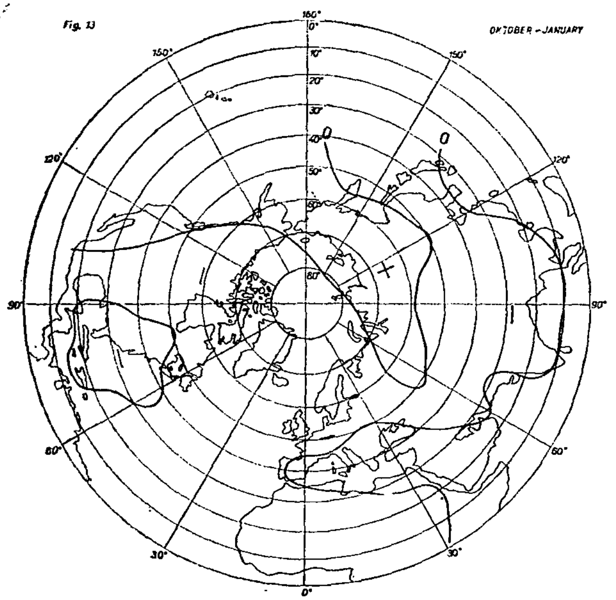

Fig. 13. The regions of the northern hemisphere at which the October mean monthly temperature has an information content relating to the January mean temperature at Szeged

climatologic prognostic. Because according to (1) the entropy of a forecast with two categories:

$$H = p \log_2 \frac{1}{2} + (1-p) \log_2 \frac{1}{1-p}$$

this has a maximum if $p=0{,}5$, $1-p=0{,}5$. $H_{\max}=1$ bit. With each information quantity gain the entropy diminishes

$$H = H_{\max} - I = p \log_2 \frac{1}{p} + (1-p) \log_2 \frac{1}{1-p}$$

this way with I the distribution $(p, (1-p))$ can be defined. E. g. concretely taking the first month before February, in this case the maximal information quantity is 0,14 bit, so

$$1 - 0{,}14 = p \log_2 \frac{1}{p} + (1-p) \log_2 \frac{1}{1-p}$$

from where $p=0{,}28$, $1-p=0{,}72$, consequently, since the actual January value of the temperature field is known, a $p=0{,}28$, $1-p=0{,}72$ prognostic can be given for mean temperature in Szeged, in February and because this relation is positive in the case of a January mean temperature below the average the probability of a below average February mean temperature is $p=0{,}72$, in the case of a January above average it is $p=0{,}28$. This method was applied for the period 1951—1960. This "archive" prognostic proved to be true in 65% of the cases as opposed to the 50% of a climatologic prognostic. The low efficiency of our forecast can be understood since a very plain predictor was applied though the presently available complicated proceedings which involve more calculations do not give better results either.

RELATIONSHIP OF THE WHEAT-PRODUCTION TO THE OECOLOGICAL POTENTIAL IN THE SOUTHERN PLAIN, HUNGARY

by

Yolande Palotás—L. Makra

A búzatermesztés és az ökológiai potenciál kapcsolata a Dél-Alföldön. A Dél-Alföldön a búzatermesztés szempontjából fontos három megyében megvizsgáltuk 25 mezőgazdasági termelőszövetkezet három éves termésátlagait faktor- és path-analízissel. Megállapítottuk, hogy a termésátlagot befolyásoló fő ökológiai faktorok fontossági sorrendben a következők: a talaj minősége, a júniusi középhőmérséklet és az áprilisi csapadékösszeg. A búzatermesztés szempontjából legkedvezőbb területek kiválasztásánál e tényezők figyelembe vétele alapvető fontosságú.

Three-year average fields of agricultural co-operatives in 25 villages of three important wheat-producing South-Plain counties are examined with factor- and path-analysis. It has been established that the main oecological factors influencing average yield are, in order of importance, as follow: the quality of the soil, the average June temperature and April rainfall. This emphasises the importance of taking all these factors into consideration, when selecting the most favourable areas from the aspect of wheat production.

The southern part of the Great Hungarian Plain yields more than 23% of the country's wheat crop. (*Fig. 1*). Here average yields are always higher than the national average. In the future oecological factors have to be observed to a greater extent so that this territory, too, could contribute to the execution of the cereals program. Our present study offers to contribute to the efficiency of the production of this plant by exploring the relationship of wheat production and eocological factors.

The investigation was based upon the production data of agricultural cooperatives. A full-scale survey has been done on cooperative fields of the southern Plain.

The most important oecological factors — from the point of view of wheat production — are soil and climatic factors. Soil quality used to be characterised with gold crown value — a widely used expression even now, from climatic factors temperature and precipitation were put into the highlight. This latter was investigated first of all in its April, May, June and July distribution and volume. In case of temperature the mean temperatures of the same periods were considered.

Speaking of gold crown value we have to state that that wheat is not grown in the best soil in our territory. In Csongrád county the average gold crown values of wheat growing areas and the gold crown value of the total arable land of the co-operatives were compared and the result was a shift of 36 gold crowns into negative direction.

Wheat is planted in soil of lesser quality because it has less demands on soil as maize or sugar-beet. (It has to be stated, however, that the average wheat crop would be even more favourable on a more valuable soil.)

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gold crown value: index number of soil classification expressing netto income of the unit of area in 1875 money value. Higher value means better quality. Hungarian average: 11.

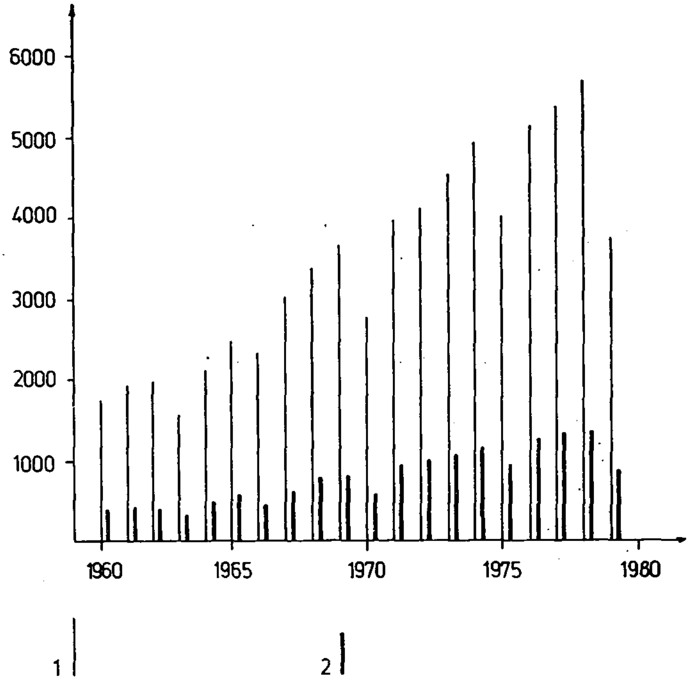

Fig. 1. Rate of national crops on the Southern Plain (1966—1980)
1 = national data
2 = Southern Plain

As it is known, the quality of soil may show quite big differences on the areas of individual counties with a surface of 4,2—8,4 km² each. From the numerous factors classifying soil quality one was put into the highlight, the gold crown value (which is justly criticized, but for the time being can't be replaced with a more adequate term) and this was confronted with average crop. The obtained result showed that the correlation relationship was 0,773 between gold crown value and the average per hectare crop. This straight relationship means that in our area yields are in 59,7% determined by the quality of the soil characterised by the gold crown value.

The forceful effect of soil quality in influencing crops is demonstrated from different aspects by the resemblance of the respective maps of the three territories each classified by their different soil characteristics — that of wheat crops and the gold crown value map of wheat producing areas (*Fig. 2, 3*).

According to our aims we investigated to what extent wheat crops depend on the chosen variables in Békés and Csongrád counties. The investigation was extended to the cooperatives of 25 villages. These villages are as follows:

1. Apátfalva
2. Ásotthalom
3. Battonya
4. Békés
5. Békéscsaba
6. Békéssámson
7. Békésszentandrás
8. Csongrád
9. Csorvás
10. Földeák
11. Gyoma
12. Gyula

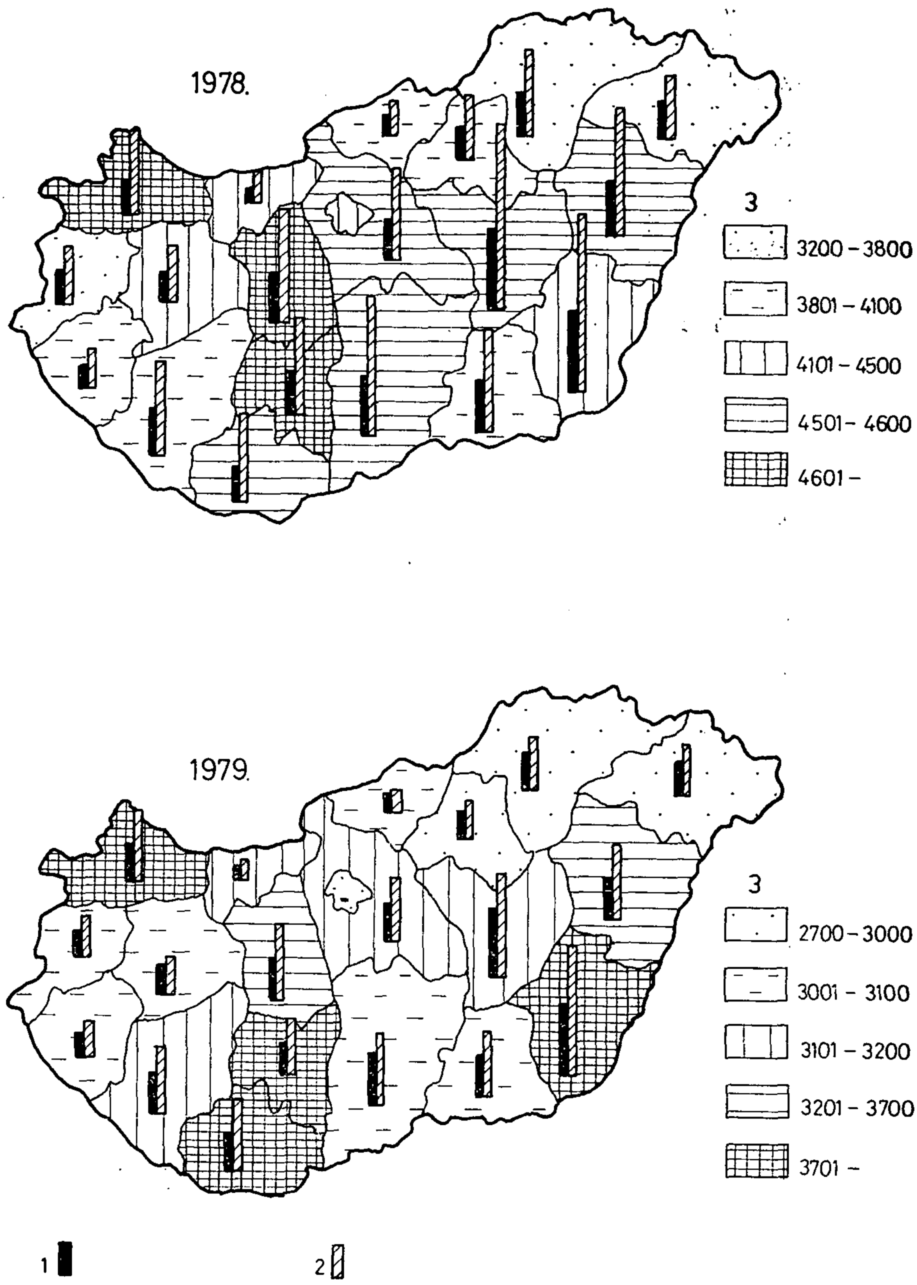

Fig. 2. Characteristics of wheat production in the different counties
1 = area where wheat is grown (50 000 ha)
2 = crop (100 000 t)
3 = average wheat yield (kg/ha)

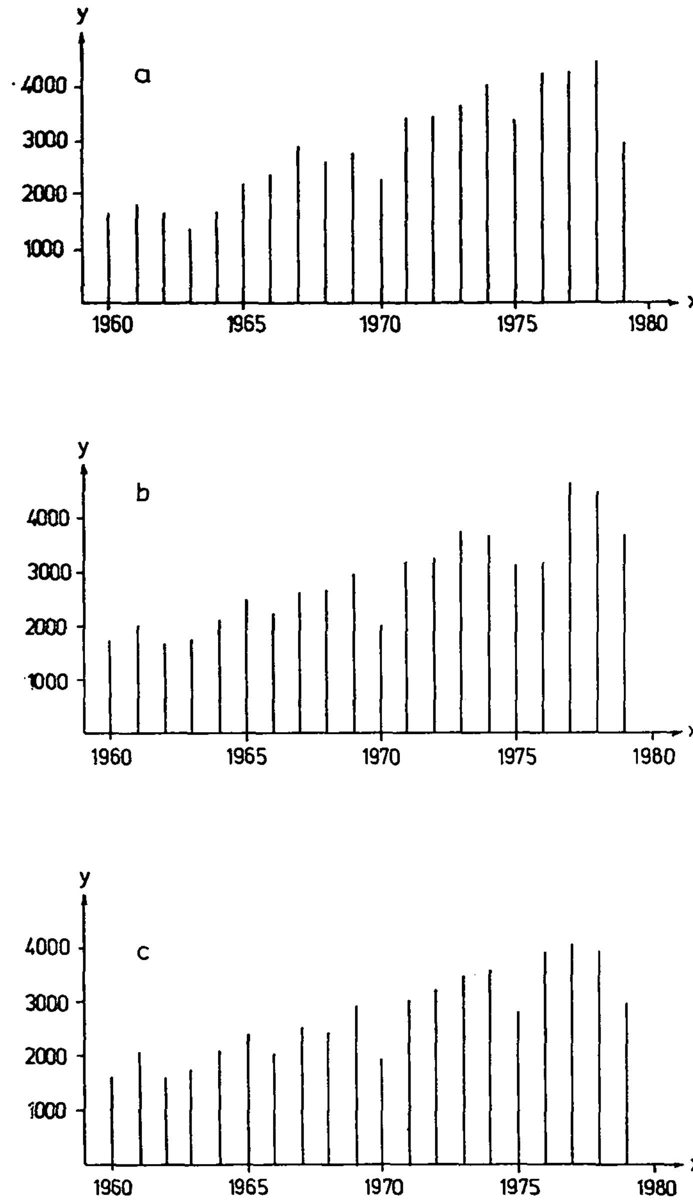

Fig. 3. Average wheat yields in the counties of the Southern Plain
x = year
y = kg/ha
a = Bács-Kiskun county
b = Békés county
c = Csongrád county

13. Hódmezővásárhely
14. Kistelek
15. Kondoros
16. Köröstarcsa
17. Lökösháza
18. Makó
19. Méhkerék
20. Mezőkovácsháza
21. Orosháza
22. Sarkad
23. Szarvas
24. Szeged
25. Szentes

The choice of the sample was motivated by the existence of the necessary data. The index of the average values of 3 years between 1977—79 were taken as a basis of our calculations *(Tab. 1)*. The following variables were considered:

Table 1

Average values of the variables considered (1977—1979)

x_0	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
4756	39	2423	13,2	86	14	36	68	9,2	16,6	19,3	20,0
2145	10	1200	20,0	49	41	50	38	10,5	17,2	20,6	21,5
4608	31	510	77,0	97	33	57	55	9,5	16,8	19,9	20,8
5805	37	2467	34,4	83	21	87	40	9,4	17,4	20,6	21,0
5475	27	2712	48,2	57	13	34	36	9,4	16,7	19,9	20,4
4348	30	470	42,0	57	48	30	45	8,9	15,9	19,5	20,3
4405	24	620	40,0	51	17	51	25	9,7	17,1	20,2	20,7
4763	39	2423	69,7	53	83	118	59	10,0	13,5	17,6	18,7
2035	10	2743	12,7	60	124	129	48	11,1	14,7	19,0	20,0
4727	31	2094	99,2	44	74	88	56	10,7	14,5	18,7	19,6
5314	37	2467	33,4	42	81	148	50	10,8	14,5	18,8	20,1
5784	27	2712	100,0	21	98	131	59	10,0	13,8	18,0	18,9
3959	29	2630	99,2	41	114	123	48	9,9	13,7	18,2	19,4
4454	26	2045	99,2	34	118	184	70	10,6	14,3	18,8	19,5
4247	39	2423	69,7	45	59	68	51	9,3	16,7	21,3	18,5
782	11	1938	70,0	18	34	72	34	10,2	17,8	22,6	19,5
4370	31	1061	66,0	35	25	68	51	9,6	17,2	22,1	19,6
4715	37	2467	34,0	40	35	86	38	10,0	17,6	21,9	19,1
3676	27	2712	100,0	21	14	62	44	9,5	17,1	21,8	18,7
2810	29	1233	69,0	21	12	78	38	9,6	17,4	21,7	18,8
2880	24	1142	89,0	16	31	77	50	9,9	17,3	22,2	19,3
2308	10	1870	20,0	64	89	83	38	9,1	13,8	19,6	20,5
5274	31	580	99,0	73	49	46	39	8,9	13,9	19,4	20,7
4469	31	600	90,0	67	46	73	24	8,1	13,4	18,5	19,7
4694	23	760	99,0	64	52	73	20	9,0	13,8	19,4	20,3

1. Resultvariable x_0: *wheat crop (kg/ha)*
2. variable x_1: *gold crown value of the soil*
3. variable x_2: *production cost of wheat (Ft/q)*
4. variable x_3: *Being part of a production system (in the percentage of total wheat growing area)*
5. variable x_4: *rainfall in April (mm)*
6. variable x_5: *rainfall in May (mm)*
7. variable x_6: *rainfall in June (mm)*
8. variable x_7: *rainfall in July (mm)*
9. variable x_8: *mean temperature in April* (°C)
10. variable x_9: *mean temperature in May* (°C)
11. variable x_{10}: *mean temperature in June* (°C)
12. variable x_{11}: *mean temperature in July* (°C)

In dataprocessing the method factoranalysis was employed.

The *R* matrix of the simple correlation coefficients was first determined, as demonstrated in *Tab. 2*.

Table 2

Correlation matrix formed from wheat producing indexes of some villages in the Southern Plain
0 : p≦0,05 , x : p≦0,01 , ♯ : p≦0,001
n = 25

	1	2	3	4	5	6	7	8	9	10	11	12
1.	1											
2.	0,773 ♯	1										
3.	0,076	0,125	1									
4.	0,208	0,174	−0,157	1								
5.	0,332	0,200	−0,239	−0,347	1							
6.	−0,051	—0,206	0,345	—0,135	—0,090	1						
7.	0,052	0,000	0,465*o*	0,200	−0,323	0,789 ♯	1					
8.	0,197	0,335	0,421*o*	0,064	−0,059	0,378	0,426*o*	1				
9.	−0,260	−0,260	0,473*o*	−0,152	−0,405*o*	0,461*o*	0,604*x*	0,421*o*	1			
10.	−0,257	−0,001	−0,052	−0,328	−0,173	−0,752 ♯	−0,496*o*	−0,105	0,047	1		
11.	−0,438*o*	−0,149	−0,133	−0,107	−0,381	−0,655 ♯	−0,417*o*	−0,270	−0,045	0,859 ♯	1	
12.	0,035	−0,324	−0,419*o*	−0,446*o*	0,645 ♯	−0,164	−0,346	−0,325	−0,101	0,051	−0,120	1

When analysing this correlational matrix special attention has to be devoted to the cost of production. Generally it can be stated that it has a loose connection with the other variables. The cost of production is in the closest relationship with the mean temperature in April ($r=0,473$) and with the rainfall in July ($r=0,465$). The correlation coefficient between soil quality and the cost of production gave the value of 0,125. This rather loose connection reflectes that the quality of soil cannot be overvalued from the point of view of wheat growing, because this is not the main factor in forming of production costs. Generally, the upper limit of production costs cannot be determined on the basis of soil quality — because of factors beyond human influence, among others. (e. g. foliage manure used in case of drought increases the endurance of the plant, but if there is no rainfall within 4—5 days, the increase in cost does not give a subsequent increase in outcome.

There are however, possibilities, as for example providing modern appliances making possible to finish sowing and reaping in 10—10 days if started at a given optimal moment.

As it is well-known, the establishments belonging to a production system have better results as those not acting in its frameworks. This is due on one hand to eventually more favourable natural endowments, on the other hand it is a consequence of better technical provisions and a set discipline in technology. The production system provides general technological frames, which have to be adapted to the different establishments, even to individual fields considering local experience. According to this, the maximal allowed value of different types of costs is rather varying in space and time. The issue is further complicated by the fact that harmony plays an essential role among the factors of production. Investigating the crop/belonging to a production system rate resulted in an "r" of *0,208*.

For dataprocessing the main factor method of factor-analysis was applied. Four factors were selected on the basis of eigenvalues and the appertaining eigenvectors essential to this method, which are represented with their factor-weights in *Tab. 3.*

Table 3

Factor gravities

Factors	$f(1)$	$f(2)$	$f(3)$	$f(4)$
Yield (kg/ha)	0,194	0,730	0,472	0,192
Gold crown	0,125	0,492	0,768	0,270
Cost of production (Ft/q)	0,570	−0,294	0,172	0,480
System of production (%)	0,289	0,084	0,437	−0,733
Rainfall in April (mm)	−0,250	0,766	−0,314	0,345
Rainfall in May (mm)	0,867	0,025	−0,407	—0,119
Rainfall in June (mm)	0,882	−0,169	−0,093	−0,015
Rainfall in July (mm)	0,606	−0,032	0,270	0,434
Temperature in April (°C)	0,535	−0,564	−0,232	0,354
Temperature in May (°C)	−0,665	−0,509	0,300	0,389
Temperature in June (°C)	−0,638	−0,646	0,296	0,026
Temperature in July (°C)	−0,443	0,382	−0,659	0,245

(The number of the elements is 25. On 1% of significance level the threshold value of the correlation coefficient is 0,49.)

As it can be seen from above factor 1 strongly correlates with production costs (x_2), with the rainfall in May (x_5), June (x_6) and July (x_7), and with the mean temperature in April (x_8), May (x_9) and in June (x_{10}) — though with these latter two in a negative sense. Factors *2* and *3* seem to be more important, since they are in a significant correlation with the target quantity. If a factor strongly relates to the target quantity and the variables gravitate towards these factors, the same variables consequently correlate with the target quantity. This would mean that crop is in a significant positive correlation at high factor gravities with the soil's gold crown value (x_1) — factor *2* and *3*, with rainfall in April (x_4) — factor *2* while in a similarly negative correlation with the mean temperatures in April (x_8), May (x_9), June (x_{10}) — factor 2 and in July (x_{11}). — factor 3. At factor *4* only the production system has a special gravity.

To give a special classification of the influence of variables $x_1, x_2, \ldots, x_{11}$, factor gravities of factors F_2, F_3 and F_4 have to be transformed for factor F_1. (*Tab. 4*).

Table 4

The special transformation of the variables considered

	F_1	Classification
1.	0,911	—
2.	0,876	1
3.	0,076	9
4.	0,201	7
5.	0,470	3
6.	−0,031	10
7.	0,001	11
8.	0,335	5
9.	−0,384	4
10.	−0,312	6
11.	−0,495	2
12.	−0,078	8

As expected, soil's gold crown value (x_1) is in the first place. The second from the variables considered is the influence of mean temperature in June (x_{10}) on the target quantity. On places 3—4 are the rainfall (x_4) and mean temperature in April (x_8). According to available data minimal influence is due to appertaining to a production system (x_3) and to rainfall in May (x_5). In both cases a signifant role is played by the different soil characteristics (quality, type, water tendencies of the soil etc.).

With the help of factoranalysis it can be recognized, to what extent variables reflect a target quantity. To obtain a result, the determination coefficient R^2 of the target quantity has to be calculated which is the square of the correlation coefficient belonging to the target quantity — calculated after a special transformation of factor gravities (square of communality h_1^2): $R^2=h_1^4=0{,}689$, which means that the variation of the target quantity is due in 68,9% to the variance of variables.

We introduce an analysis of same basic data with a few theoretical consideration. In a regression analysis it is often expected from a binary correlational coefficient to reveal to what extent independent variable x influences dependent variable y. If, however, independent variable x is dependent from one or more independent variables influencing y, correlation coefficient r_{yx} contains the influence of these too.

In order to reveal a deeper connection between the dependent variable (y=yield) analysed in course of our survey and the independent variables (x_i; $i=1, 2\ldots11$) the observed connections are broken up into the direct influence of the independent variable plus the indirect influence of other variables. This breaking up, which method is a special case of pathanalysis by *S. Wright* (1921), will be calculated for the multiple correlational coefficient R^2. When breaking up R^2, the whole correlational system is broken up into direct and common influences. The indirect influences are melting into the common influences of independent variables. Formula of breaking up:

$$R^2 = \sum p_i^2 + \sum 2p_i p_j r_{ij},$$

where p_i is the path-coefficient (standardised partial regressional coefficient). In our original formula p_i^2 expresses the direct influence of variable x_i; component $2p_i p_j r_{ij}$ can be explained as the joint influence of x_i and x_j; r_{ij} is the correlational coefficient of variables x_i and x_j $(i=j;\ i,j=1, 2,\ldots, 11)$ (*Sváb J. 1973*).

The obtained direct and joint effects show that the distribution of dependent variable y (yield) in what percentage was directly influenced by the individual independent variables x_i $(i=1,2,\ \ldots,\ 11)$ and what was their joint effect. The sum of direct and joint effects in pairs gives the multiple determinational coefficient R^2. Adding to this the square of path-coefficient of deviation component P_E^2, 1 or 100% is obtained. It is obvious that P_E^2 expresses the quantity that cannot be explained with the method of multiple regression analysis from a variation of dependent variable y:

$$P_E^2 = 1 - R^2.$$

Our data were processed with the path-analysis, the obtained results are understood on the basis of data in *Tab. 5* and *6*. Analysing direct and joint effects in pairs it can be stated that the dispersion of wheat crops (*Fig. 4*) was conclusively due to the direct influence of the soil's gold crown value (80,5%) on the investigated area during the given period. A strong direct influence can be observed in the cases of mean temperature in July (50,6%), rainfall in April (13,7%), as well as in the case of mean temperature in June (12,9%).

Table 5

Breaking up of the multiple determinational coefficient R^2
Path-analysis

	p_i	p_i^2		total effect
Gold crown	p(1)= 0,897	(80,5%)	r(Y,1)= 0,7726	69,3%
Cost of production	p(2)= 0,266	(7,1%)	r(Y,2)= 0,0763	2,0%
Production system	p(3)= 0,221	(4,9%)	r(Y,3)= 0,2075	4,6%
Rainfall in April	p(4)= −0,370	(13,7%)	r(Y,4)= 0,3315	−12,3%
Rainfall in May	p(5)= −0,036	(0,1%)	r(Y,5)= −0,0505	0,2%
Rainfall in June	p(6)= 0,062	(0,4%)	r(Y,6)= 0,0519	0,3%
Rainfall in July	p(7)= −0,031	(0,1%)	r(Y,7)= 0,1965	−0,6%
Temperature in April	p(8)= −0,223	(5,0%)	r(Y,8)= −0,2597	5,8%
Temperature in May	p(9)= 0,048	(0,2%)	r(Y,9)= −0,2572	−1,2%
Temperature in June	p(10)= −0,358	(12,9%)	r(Y,10)= −0,4377	15,7%
Temperature in July	p(11)= 0,712	(50,6%)	r(Y,11)= 0,0349	2,5%
				86,3%

On the basis of all the influences which are the resultant of direct and joint effects in pairs it can be observed that the dispersion of crops is conclusively caused by the soil's gold crown value (69,3%); the role of mean temperature in June (15,7%) as well as that of the rainfall in April (−12,3%) can be mentioned.

Direct and joint influences explain crop dispersion in 86,3%. Accordingly:

$$P_E^2 = 1 - 0{,}863 = 0{,}137 = 13{,}7\%.$$

That is, the total crop dispersion as dependent variable only in 13,7% cannot be accounted for with the linear effect of independent variables x_i $(i=1,2,\ \ldots,\ 11)$.

Table 6

Breaking up of the multiple determinational coefficient R^2

	$2p_ip_jr_{ij}$
Gold crown-cost of production	5,9%
Gold crown-production system	6,9%
Gold crown-rainfall in April	−13,3%
Gold crown-rainfall in May	1,3%
Gold crown-rainfall in June	0,0%
Gold crown-rainfall in July	−1,9%
Gold crown-temperature in April	10,4%
Gold crown-temperature in May	0,0%
Gold crown-temperature in June	9,6%
Gold crown-temperature in July	−41,3%
Cost of production-production system	− 1,8%
Cost of production-rainfall in April	4,7%
Cost of production-rainfall in May	− 0,7%
Cost of production-rainfall in June	1,5%
Cost of production-rainfall in July	− 0,7%
Cost of production-temperature in April	− 5,6%
Cost of production-temperature in May	− 0,1%
Cost of production-temperature in June	2,5%
Cost of production-temperature in July	−15,8%
Production system-rainfall in April	5,7%
Production system-rainfall in May	− 0,2%
Production system-rainfall in June	0,5%
Production system-rainfall in July	− 0,1%
Production system-temperature in April	1,5%
Production system-temperature in May	− 0,7%
Production system-temperature in June	1,7%
Production system-temperature in July	−14,0%
Rainfall in April-rainfall in May	− 0,2%
Rainfall in April-rainfall in June	1,5%
Rainfall in April-rainfall in July	− 0,1%
Rainfall in April-temperature in April	− 6,7%
Rainfall in April-temperature in May	0,6%
Rainfall in April-temperature in June	−10,1%
Rainfall in April-temperature in July	−34,0%
Rainfall in May-rainfall in June	− 0,4%
Rainfall in May-rainfall in July	0,1%
Rainfall in May-temperature in April	0,7%
Rainfall in May-temperature in May	0,3%
Rainfall in May-temperature in June	− 1,7%
Rainfall in May-temperature in July	0,8%
Rainfall in June-rainfall in July	− 0,2%
Rainfall in June-temperature in April	− 1,7%
Rainfall in June-temperature in May	− 0,3%
Rainfall in June-temperature in June	1,9%
Rainfall in June-temperature in July	− 3,1%
Rainfall in July-temperature in April	0,6%
Rainfall in July-temperature in May	0,0%
Rainfall in July-temperature in June	− 0,6%
Rainfall in July-temperature in July	1,4%
Temperature in April-temperature in May	− 0,1%
Temperature in April-temperature in June	− 0,7%
Temperature in April-tempearature in July	3,2%
Temperature in May-temperature in June	− 3,0%
Temperature in May-temperature in July	0,3%
Temperature in June-temperature in July	6,1%

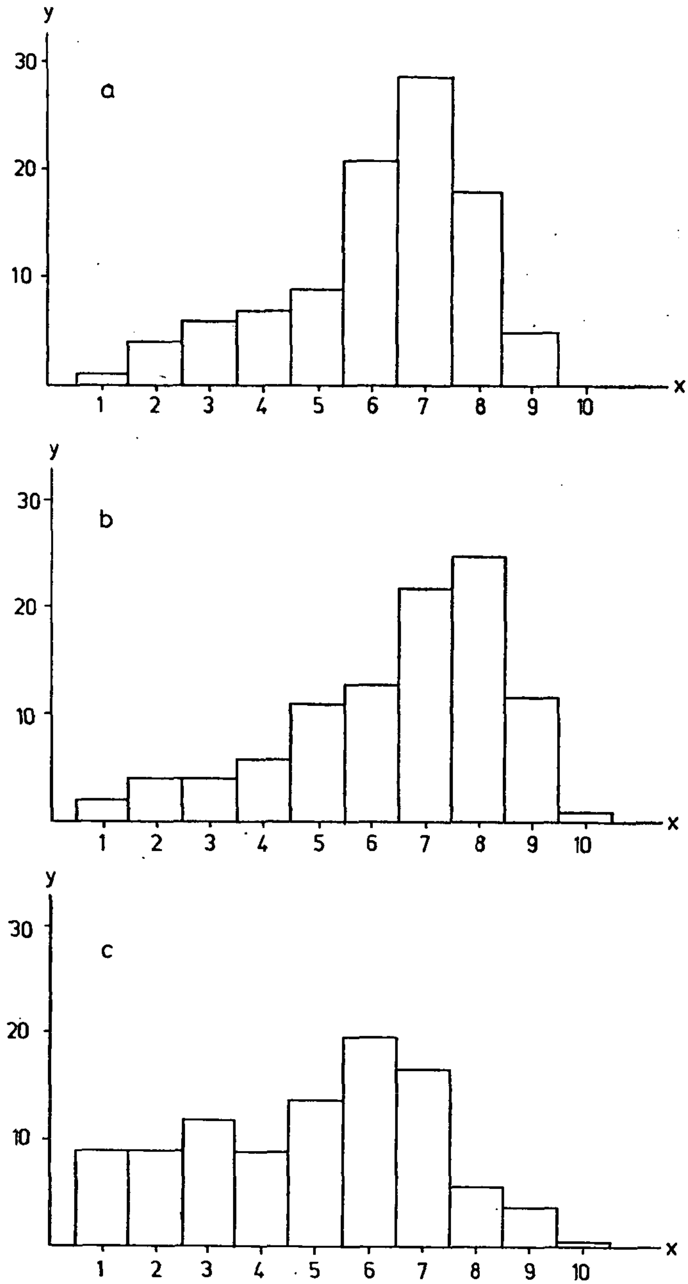

Fig. 4. Frequency polygon of the dispersion of average wheat crops in the different cooperatives (1980)
x=kg/ha
y=%
a=Bács-Kiskun county
b=Békés county
c=Csongrád county

Dataprocessing was executed with two different methods and with the help of computer type HP 9831. Both obtained results reflect that wheat crops stand in close relationship with the soil's gold crown value, rainfall in April and with mean temperature in June. The path-analysis, however, attributes more significance to the variables considered at the dispersion of crops.

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THE SPATIAL AND TEMPORAL VARIABILITY OF DROUGHT IN THE SOUTHERN PART OF THE GREAT HUNGARIAN PLAIN

by

L. Makra—Á. Kiss—Yolande Palotás

Az aszály tér- és időbeli változékonysága a Dél-Afföldön. A tanulmány a Dél-Alföld három megyéjében (Bács-Kiskun, Békés és Csongrád), valamint Szolnok megyében az aszály tér- és időbeli változásait elemzi, továbbá egyes haszonnövények terméseredményeinek az időjárási tényezőkkel való kapcsolatát vizsgálja. A vizsgálatok 14 állomás 1953—1983 közötti 31 éves idősorait, valamint a búza, a kukorica és a cukorrépa megyénkénti átlagos terméshozamának 1960—1983 közötti 24 éves idősorait dolgozzák fel.

A Dél-Alföldön a vízellátottság — bár térben és időben igen változékony — minden esztendőben negatív mérleggel zárul, sőt egyes években félsivatagi jelleggel párosul. A szeszélyes vízellátottság a termőtalaj vízkészletének változásaiban élesen tükröződik; a nyári félévben is várható maximális víztelítettség, de a nyár közepétől egyre gyakoribb az aszálykárt okozó szűkös talajnedvesség.

Megállapítható, hogy a fentebb említett haszonnövények terméshozama az agrotechnika színvonalának emelkedése ellenére is erősen függ a természeti tényezőktől. tehát az öntözés és a megbízható öntözőbázis kiépítése a Dél-Alföldön feltétlenül kívánatos.

The study analyses the spatial and temporal changes of drought in three counties of the southern part of the Great Hungarian Plain (Bács-Kiskun, Békés and Csongrád counties) as well as in Szolnok county, furthermore it investigates the relationship of the crop results of certain cultivated plants to the meteorological factors. In this study have been processed the time series of the 31 years for the period 1953—1983 at 14 stations, as well as the time series of the 24 years for the period 1960—1983 of the average yield of wheat, corn and sugar-beet in each county.

The water supply in the southern part of the Great Hungarian Plain — although it is spatially and temporally very changeable — has a negative balance in each year, in some years it is even accompanies with a semi-desert character. The changeable temporal course of precipitation strongly manifests itself in the stock of soil water; the greatest water saturation can be expected even in the summer half-year, but the poor soil humidity causing drought damage is more and more frequent from the middle of the summer season on.

It can be set down that the crop results of the above-mentioned cultivated plants considerably depend on natural factors even in spite of the rise of agrotechnics, consequently the irrigation and the extension of a reliable irrigation base in the southern part of the Great Hungarian Plain is by all mean desirable.

Plant cultivation is that branch of our economy which responds in the most sensitive way to the changes of weather. The changeable weather of the recent period has emphasized the different problems connected with this question, first of all how the quantity and quality of agricultural production and so the economic output are modified to negative or positive direction from the average of many years by the changes of certain weather components.

The change of different factors of weather independently results in remarkable deviations in the yields but if the different factors change simultaneously their economical effect can be manifested in a stronger way.

As compared to the past the nowadays widespread modern methods of agriculture may moderate the increase or decrease of agricultural yield caused by weather changes, but the use of these methods means a substantial increase of expenses. This means that we have to remain competitive in every respect among more unfavourable international marketing circumstances and facing higher expenses. And this requires even more *the most effective utilization of our natural resources.* It must be noted that we have huge unexploited resources in this respect. In order to mobilize these resources the deep knowledge of individual or simultaneous effects of different elements of weather on plant production is necessary. According to the present state of science we know very little about this extremely complex system which has direct and indirect influence on agriculture with a lot of uncertainty factors, not speaking about the practical utilization. During our studies we have narrowed down this complicated relationship because of practical reasons.

The amount of precipitation during the growing season and related to this the variation of the water content in the upper layer of the soil have a crucial importance in the agricultural production. Since the greatest part of the root of our cultivated plants can be found in the top one-meter thick soil, it is mainly the water-content changes of this one-meter thick soil stratum is which is important, for the large scale cultivation. The experiences of a number of years show that on our arid plain the water content of the soil decreases so much during the vegetation period that it must be irrigated in order to gain a plentiful yield. At the same time it is characteristic of our changeable climate that often, sometimes even in the summer-time, because of the abundant amount of precipitation the upper soil stratum gets saturated by water, for a longer or shorter period there is excess water, and because of this a large amount of inlandwater shows up in the deeper regions of the Plain. After all we have to take into account both extremities, the destroying drought and harmful excess water, and one of the most important tasks of the Hungarian climatology is to document these phenomena and their interactions.

The drought as well as the abundant water is the complex result of different meteorological processes, thus it would be a one-sided and wrong point of view to study the occurance of these events on the basis of only amount of precipitation. Their real manifestation is reflected in the amount of soil water, which is determined by the uptake and release of water of the soil with a given structure and set of physical parameters. The uptake of water is supplied by the precipitation among natural conditions while the release of water is a result of the evaporation and flow of water. In flat areas the flow is negligible so we will not take it into account.

In our studies we consider a simplified soil structure model at every sampling point reaching from the surface to the depth of one meter and we consider its utilizable (available) water capacity [1], which can be accepted as competent to the soils around the examined points. Furthermore we suppose in our model that there is no lateral upward or downward transport of water (capillarity effect) in a given volume. The first assumption is reasonable for plain regions but the second one is a necessary simplification of reality (assumption of isolated soil volume) still as working hypothesis it can be well used. With these assumptions the uptake of water, V_b, during a given time-period can be taken to be equal to the amount of precipitation while the loss of water, V_k, is supposed to be equal to the evaporated amount, so that for a given period there exists the relationship:

$$V_b - V_k = \pm V_t \tag{1}$$

where V_t stands for the storage of water during the time-period (in our case this means the change of water content in the one-meter thick soil stratum). If the soil is saturated by water and a continuous supply of evaporated water is guaranteed, V_k will be equal to the so-called potential evaporation, and in the case of soil covered by vegetation it will be equal to the potential evapotranspiration.

If the soil is not saturated to its whole capacity the actual evapotranspiration will be less than the potentional one and it can even disappear if the available water supply of the soil stratum disappears and there is no water supply (precipitation) [2].

The determination of the variation of the water content in the soil stratum requires regular measurements of the soil humidity. But there are no long data sets concerning soil humidity so we use different mathematical methods. In the following we present shortly the principle of the calculation used in the simplified soil model [3].

If V_0 stands for the amount of water in the soil at the beginning of a given time-period and V means that at the end of the time-period, then:

$$V = V_0 + C - P \tag{2}$$

where C is the amount of precipitation, P is the evaporated amount of water (evapotranspiration) during the time-period considered. The quantity "C" appearing in the equation comes from the precipitation measurements, the value of V_0 can be determined in the simplest way by a single measurement of the soil humidity or by choosing a precipitation-rich period in the winter season when because of the negligible level of evaporation we can assume that the soil stratum is completely saturated, so V_0 can be taken to be equal to the total available water capacity. In this case the value of P is assumed to be equal to the P_p potential evapotranspiration as long as $C > P_p$ holds. The potential evapotranspiration was given by *Antal*'s relationship:

$$P_p\,(\text{mm/day}) = 0{,}9(E-e)^{0{,}7}\left(1+\frac{t}{273}\right)^{4{,}8} \tag{3}$$

where "E" and "e" are the saturation vapour pressure and the actual vapor pressure respectively, belonging to the average air-temperature of the season or month studied, and t is the average air-temperature of that period (°C).

The calculations were carried out according to the meteorological data of fourteen meteorological stations from the Great Hungarian Plain. The main parameters, the dominant soil types and the length of the time series can be found in *Table 1*.

Table 1

The parameters of the stations considered

Stations	Period under survey	Co-ordinates h	φ	λ	Soil types
Ásotthalom	1953—1971	117	46°12′	19°47′	blown sand
Baja	1931—1983	109	46°10′	18°58′	shedding
Békéscsaba	1931—1983	90	46°40′	21°07′	fields
Kalocsa	1931—1983	96	46°32′	18°59′	meadow, fields
Karcag	1951—1971	87	47°18′	20°55′	fields
Kecskemét	1947—1983	112	46°54′	19°43′	blown sand
Kiskunfélegyháza	1953—1971	102	46°43′	19°51′	blown sand
Kiskunhalas	1973—1983	132	46°26′	19°29′	blown sand
Mezőhegyes	1935—1983	100	46°19′	20°49′	sodic, fields
Orosháza	1931—1983	90	46°34′	20°40′	fields
Szarvas	1952—1983	85	46°52′	20°32′	meadow
Szeged	1931—1983	79	46°15′	20°09′	shedding, meadow
Szolnok	1952—1983	95	47°11′	20°13′	shedding, fields
Túrkeve	1953—1983	89	47°07′	20°45′	fields

During the evaluation we processed 50 000 data. The longest processed time series come from Baja, Békéscsaba, Kalocsa, Orosháza and Szeged (1931—1983, 53 years), while we have only fraction time series from Ásotthalom, Kiskunfélegyháza and Kiskunhalas, so the results that we got from the latter group are considered only informative. In order to get uniform survey — where it was possible — we analyzed the time series of different stations for the period of 31 years between 1953—1983.

For the solution of equation (2) we have to know the value of the actual evapotranspiration P as well. This depends on the amount of water available for the evaporation and on the potential evapotranspiration, and after some simplification as a good approximation we can accept the following relationship:

$$P = \frac{V}{V_d} P_p \tag{4}$$

where V stands for the water content of the soil stratum studied and V_d stands for the value of available water capacity. In our calculations on the first of March after the wet winter season in 1952/53 we assumed for the individual water content (for different soil types): $V_0 = V_d$(mm), and knowing the P_p and C values we determined the value of the water content V continuously for the first day of each month, and expressing them as the fraction of available water content in percent we got the percentage of water content of the upper one meter. (Each of the starting data was preceeded by a wet winter season.)

The data we got represent properly the characteristics of the water budget of the upper soil stratum, but at the same time they are appropriate to inform us about the frequency of arid and humid years. For the determination of humid character of climate we can use the Budiko's index of aridity [4]

$$H = \frac{P_p}{C}, \tag{5}$$

where we take into account the yearly amount of potential evapotranspiration and the yearly amount of precipitation. If $H > 1$ more water can evaporate from the soil than is supplied by precipitation, so the climate becomes arid, while in the case of $H < 1$ the uptake of water is higher than the release, so there is abundance of water so the climate is humid.

According to our estimations the characteristic average value of the index of aridity for our Plain region is between 1,46—1,80 which in *Budiko*'s classification corresponds to the prairy, what's more that type of it with unfavourable precipitation supply. When calculating the yearly aridity index on the basis of the yearly sums of P_p and C we find values which deviate significantly from the average (1,65). While the minimal average index value (1,07) is characteristic of the border between arid and humid climate territories, the maximal average aridity index (2,59) corresponds in the plant geographical sense to the half desert or even its drier type *(Table 2)*, It can be stated that — although in Mezőhegyes in about 10% of the years studied the humid character dominated — in this territory with typically arid climate the appearence of humid years is occasional. The average relative frequency of values $1 < H \leqq 1{,}5$ in this territory is even less than 50% (these values correspond in a plant geographical sense to a prairy with relatively favourable precipitation conditions), while the values $1{,}5 < H \leqq 2$ (dry steppe) appear in every third year in average and we can expect a half-desert-like climate ($H > 2$) almost in every four year in the Southern Great Plain *(Table 2)*.

Table 2

Characteristics of the aridity index ($H=P/C$) and that of the lack of water (P_p-C) in the summer half-year

Stations	Hmin	$\bar{H}$	Hmax	P_p-C min	$\overline{P_p-C}$	P_p-C max	$H>2$ %	$1,5<H\leqq 2$ %	$1<H\leqq 1,5$ %
Ásotthalom	1,13	1,65	2,39	158	371	628	21	37	42
Baja	1,06	1,57	2,87	77	345	606	16	32	52
Békéscsaba	1,04	1,63	2,29	100	354	615	16	42	42
Mezőhegyes	0,95	1,46	2,11	46	312	573	3	42	52
Kalocsa	0,99	1,56	2,24	−21	325	575	16	39	45
Karcag	0,98	1,68	2,57	97	339	526	26	26	48
Kecskemét	1,15	1,73	2,62	106	362	566	32	26	42
Kiskunfélegyháza	1,21	1,72	2,59	189	398	601	32	37	31
Kiskunhalas	1,14	1,42	2,43	4	280	544	9	18	73
Orosháza	0,94	1,66	2,72	70	361	654	29	35	36
Szarvas	1,12	1,65	2,89	108	348	553	23	39	38
Szeged	1,03	1,79	2,88	90	370	657	29	39	32
Szolnok	1,12	1,72	2,46	85	357	617	26	35	39
Túrkeve	1,15	1,80	3,14	120	404	664	42	23	35
Average	1,07	1,65	2,59	88	352	599	23	34	44

Abbreviations used: $\bar{H}$, $\overline{P_p-C}$ = the reginal average of the aridity index and that of the lack of water in the summer half-year
H_{min}, H_{max}, $(P_p-C)_{min}$, $(P_p-C)_{max}$ = the extremes of the parameters mentioned above

Using the calculated aridity index values we have plotted the isoarid curves (*Fig. 1.*) which give the rough approximation of the water supply of this region. According to these the worst water supply conditions can be found in the lower Tisza region and the territories north of the Körös rivers.

The meteorological value of shortage of water is well characterized by the difference of the values P_p and C corresponding to the summer season. It can be seen by

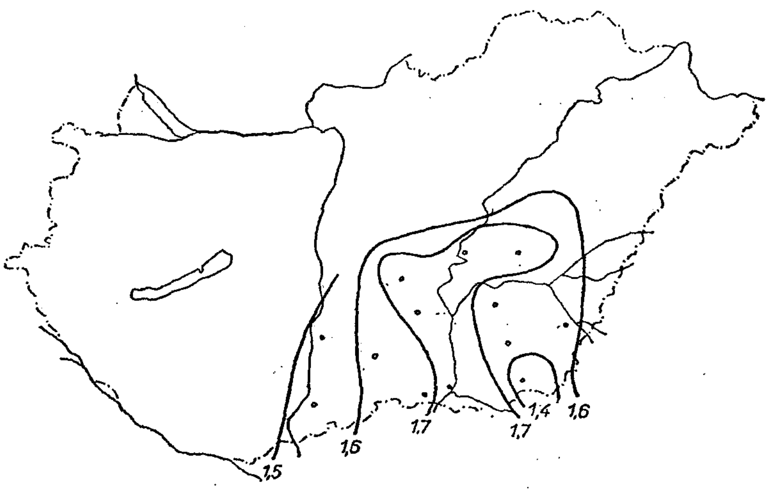

Fig. 1. The average values of the aridity index, 1931—1980

calculating and plotting these values that they strongly fluctuate from year to year. The average minimal lack of water is as little as 90 mm, (only in Kalocsa and in the summer season of only one year was the lack of water negative which means that there was abundance of water), and the average maximum value is 600 mm. The aridity index and the time series of the lack of water in the summer season as well show *(Figs 1—23)* that the driest years in the Southern Great Plain appeared between 1946—1951, and though since that time the degree of aridity with significant fluctuations has decreased it has been increasing since 1982 again. The plot of the lack of water in the summer season *(Fig. 2)* is similar to the isoarid curves *(Fig. 1)*: the driest regions in the summer season are the Lower Tisza Region and the region immediately north of the Körös Rivers. The yearly average of the potential evapotranspiration in the Southern Great Plain is 863 mm. This means that the calculated values of x the potential evapotranspiration by *Antal*'s method and by *Turc*'s equation are in fair agreement [5]. The regional average of the yearly precipitation is 551 mm, and comparing this value to that of mentioned above we obtain that we can expect 300 mm as average lack of precipitation in the Southern Hungarian Plain.

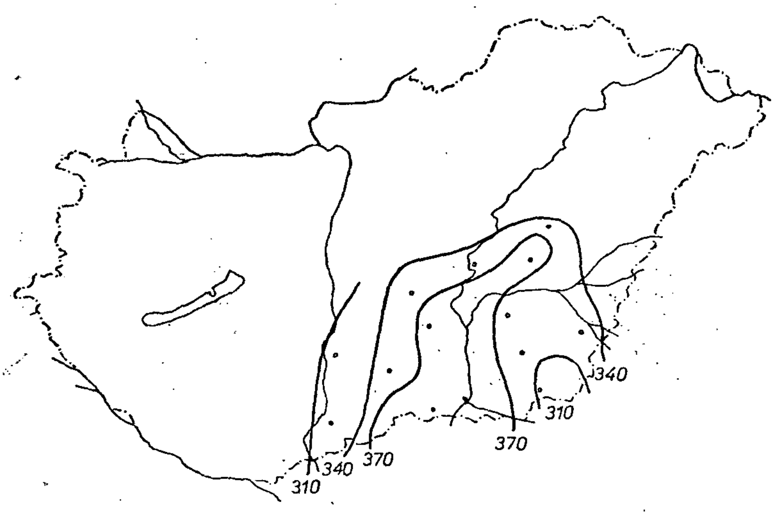

Fig. 2. The development of water deficiency in the summer season, 1931—1980

The data informing about the changes of the water content in the soil yield further information for the agriculture. According to the experience there is a need for irrigation when the water content of the soil becomes less than 80% of the available water capacity and drought exists when the water content is even less then 50% of the available water capacity [6]. The relative frequency of these soil watercontent values varies during the growing period as follows *(Table 3, Figs. 3—10, Table 4, Figs 11—18)*. In each month of the growing period the territories with the strongest necessity of irrigation are the middle part of the Great Plain and the Lower Tisza Region *(Figs. 3—18)*. In about one-third of the years from the middle of March and in 75% of the years or so from the middle of June, irrigation is necessary. Although the drying out of the soil starts at the end of summer or at the beginning of autumn, those species with earlier growing periods can be grown among much better soil humidity conditions; in about 10% of the years drought damage can be expected

Table 3

The relative frequency (%) of the event that in the growing period the water content of the soil becomes less than 80% of the available water capacity

Stations	IV	V	VI	VII	VIII	IX	X	summer half-year
Ásotthalom	11	37	74	89	74	79	89	89
Baja	13	39	61	77	71	94	84	87
Békéscsaba	29	39	58	84	68	90	97	74
Kalocsa	32	45	65	74	77	84	90	84
Karcag	42	47	58	79	79	84	89	79
Kecskemét	19	42	71	84	68	90	94	87
Kiskunfélegyháza	16	37	79	89	84	100	89	89
Kiskunhalas	9	36	36	82	55	82	91	82
Mezőhegyes	32	29	48	65	68	84	97	65
Orosháza	42	39	71	74	74	90	94	84
Szarvas	29	42	65	77	68	100	90	87
Szeged	48	58	68	81	84	94	90	94
Szolnok	52	68	77	87	84	97	90	90
Túrkeve	58	61	71	71	84	90	97	87

Table 4

The relative frequency (%) of the event that in the growing period the water content of the soil becomes less than 50% of the available water capacity

Stations	IV	V	VI	VII	VIII	IX	X	summer half-year
Ásotthalom	0	0	16	37	58	58	63	5
Baja	0	0	10	35	42	71	71	6
Békéscsaba	0	3	6	16	29	52	61	0
Kalocsa	0	0	0	23	35	45	68	0
Karcag	5	5	5	26	26	58	53	5
Kecskemét	0	6	10	52	55	58	68	6
Kiskunfélegyháza	0	0	11	42	47	79	79	5
Kiskunhalas	0	0	9	45	27	45	55	0
Mezőhegyes	0	3	3	6	23	29	52	3
Orosháza	0	3	13	23	35	58	55	6
Szarvas	0	6	10	29	32	55	74	10
Szeged	0	6	10	32	39	58	65	6
Szolnok	3	6	6	16	29	48	61	6
Túrkeve	3	3	13	29	42	58	68	10

even from the middle of May and almost in every third June there is dangerous lack of precipitation. At the end of summer the soil humidity conditions are much more unfavourable (in Aug. and in September the average relative frequency of aridity is 55—60%), which is harmful for meadow culture mostly.

In the following we would like to present the tendency of the changes of aridity in the future. To this purpose we use the method of harmonic analysis of mathematical statistics, the essence of which is that a given $y(x)$ periodical function is approximated by another function $f(x)$ which is equal or almost equal to $y(x)$:

$$f(x) = \bar{y} + \sum_{i=1}^{n} A_i \sin\left(\frac{2\pi}{T_i} x + U_i\right).$$

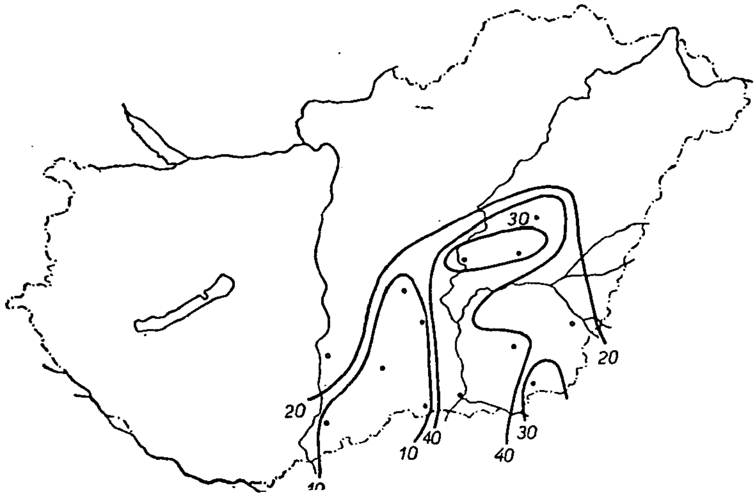

Fig. 3. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st April

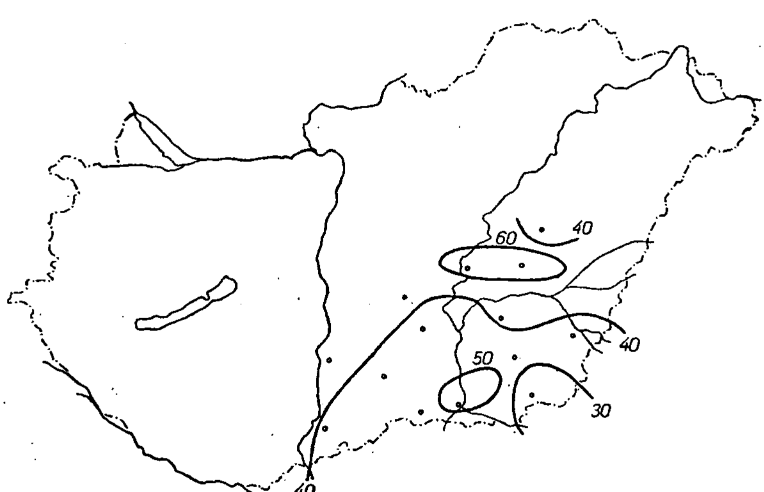

Fig. 4. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st May

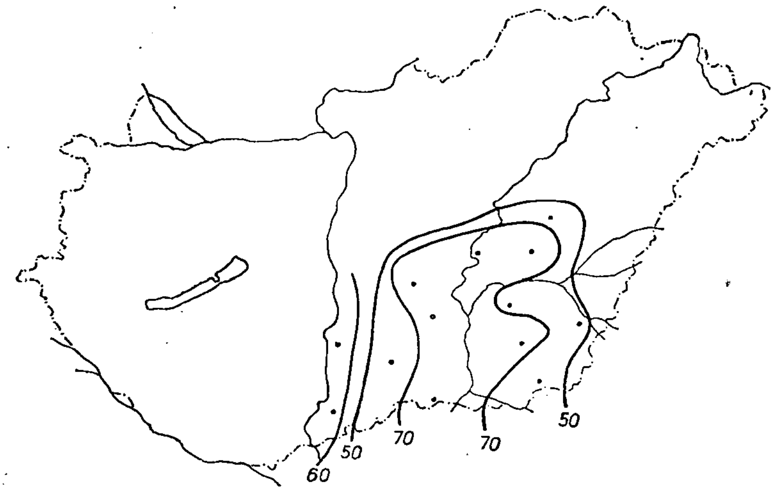

Fig. 5. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st June

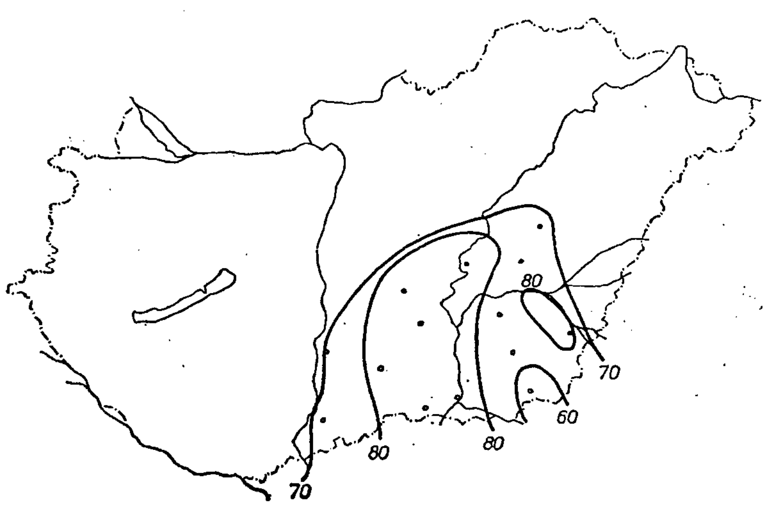

Fig. 6. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st July

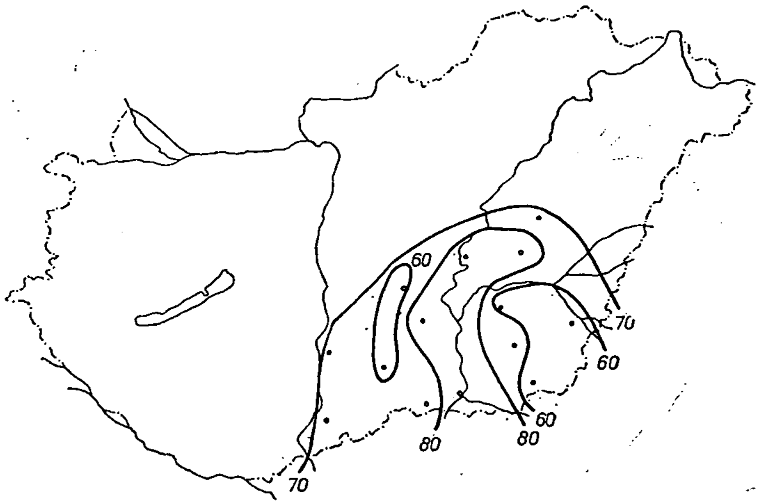

Fig. 7. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st August

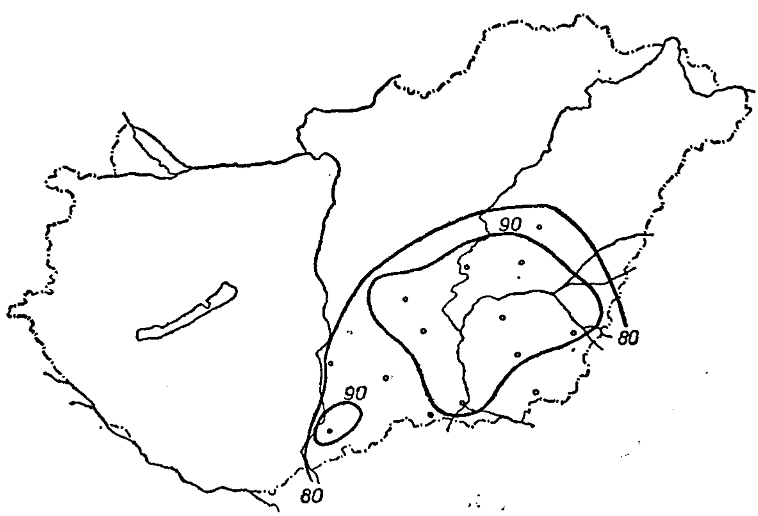

Fig. 8. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st September

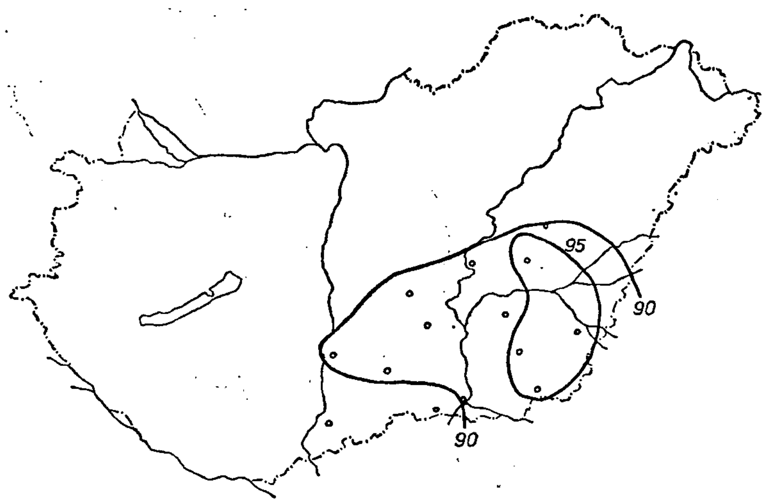

Fig. 9. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, 1st October

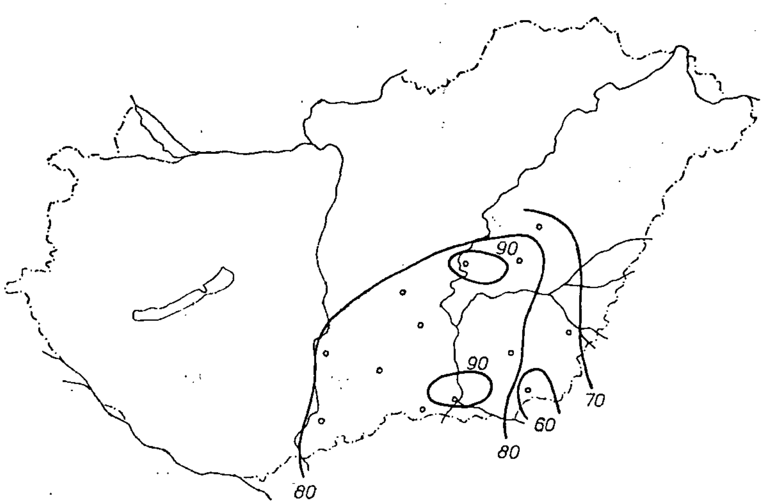

Fig. 10. The relative frequency (%) of the soil water content less than 80% of the available water capacity, 1931—1980, summer half-year

Fig. 11. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st April

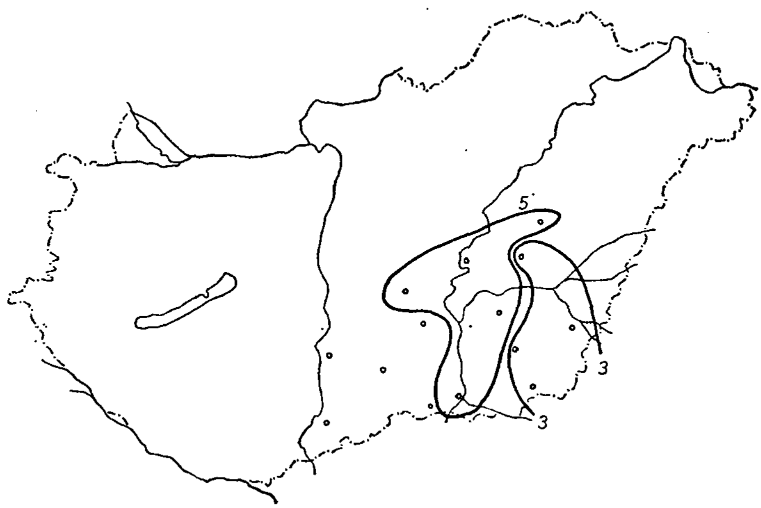

Fig. 12. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st May

where x stands for time and its actual values are: $x=0, 1, 2, \ldots, T-1$. U_i means the phase angle belonging to T_i, where $T_1=\frac{T}{2}, \ldots, T_m=\frac{T}{m}$, $\bar{y}$ is the mean value of the series.

This method is suitable for the analysis of a given time series with a given length. Increasing the length of period, the number of waves running through the time series decreases, and above a certain limit also the statistical reliability of the characteristics of statistical fluctuations decreases (amplitude, phase angle).

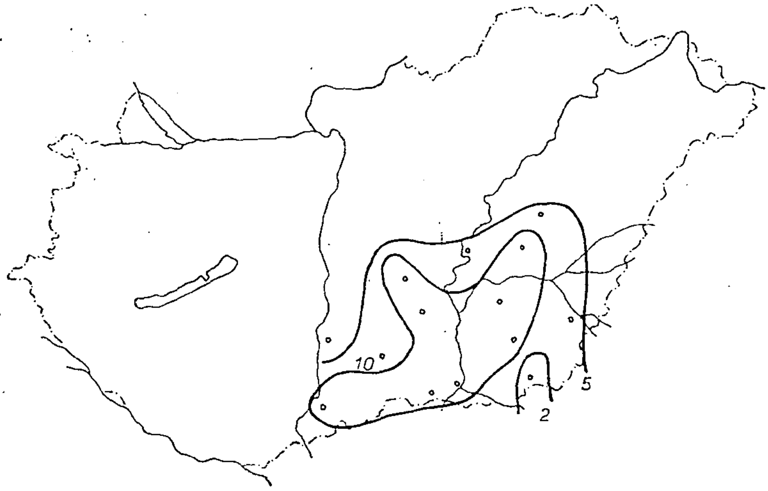

Fig. 13. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st June

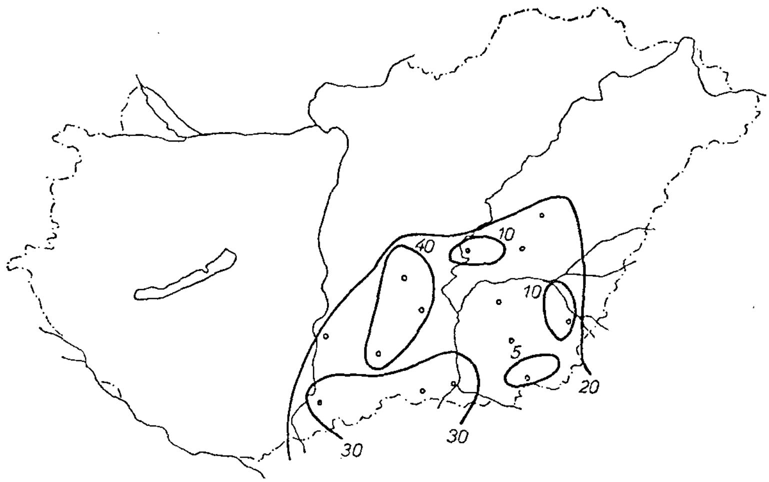

Fig. 14. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st July

By the harmonic analysis of the time series of the areal average of aridity index instead of the $\frac{A}{E}$ values of the periodical component waves we have taken into account the $\frac{A}{\text{amplitude-average}}$ values especially those, greater than one (those amplitudes greater than the average) and the corresponding phase angles were chosen. (Because of the high distorsion of expectance we used the average of the amplitudes.) Using the latter we reconstructed the time series of the areal average of the aridity index.

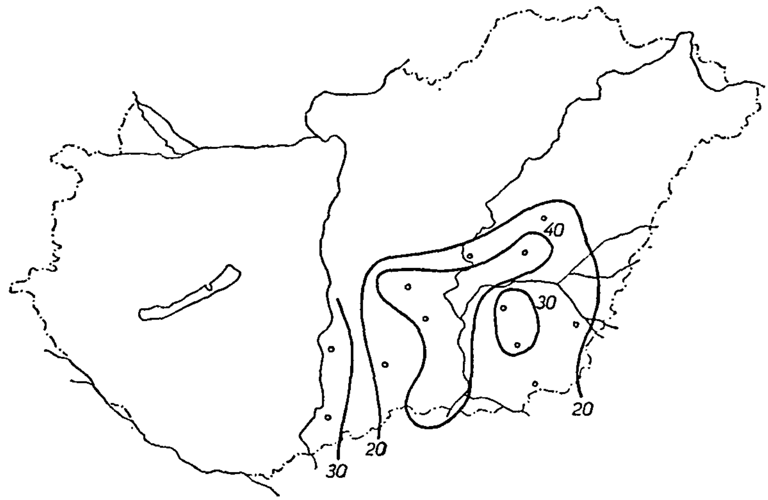

Fig. 15. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st August

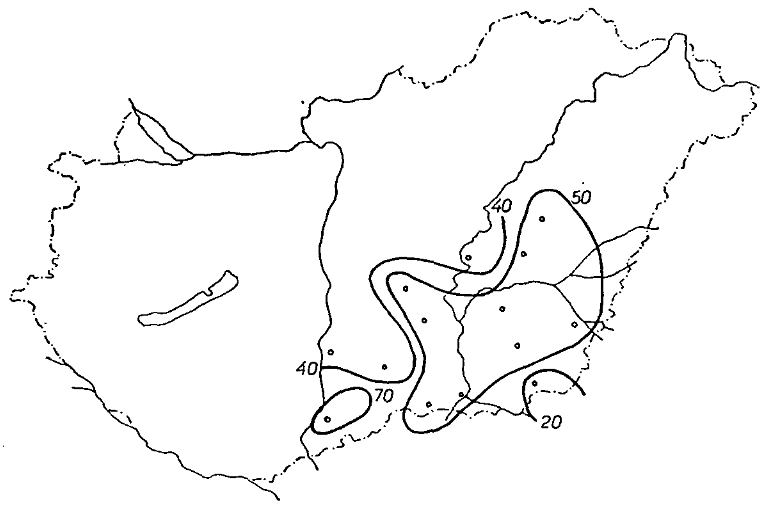

Fig. 16. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st September

The next step was to correlate the original and the calculated time series: $r=0{,}2404$, which is significant at the 5% probability level. From these results it follows that the extension of the component waves in time beyond the present provides a good approximation to the areal average of aridity index of the future. We have performed the extrapolation for the next five years, including 1984.

By taking into account the areal average (1,65) of the aridity index of the 31 years between 1953—1983 we may give a rough forecast of the tendency. According to this

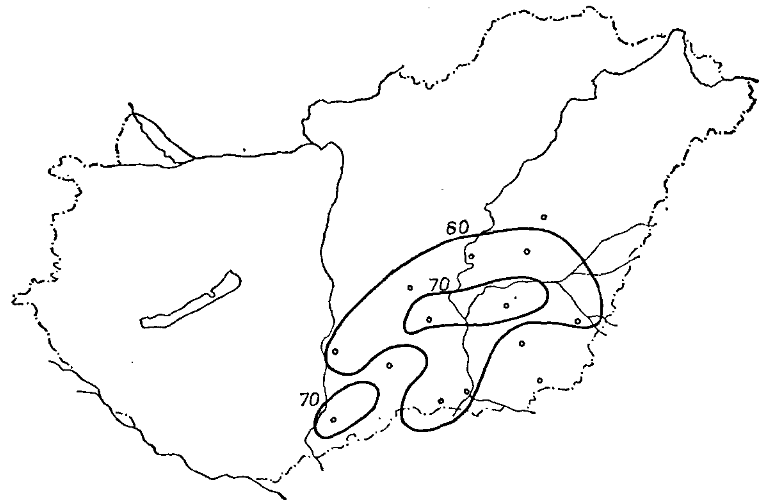

Fig. 17. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, 1st October

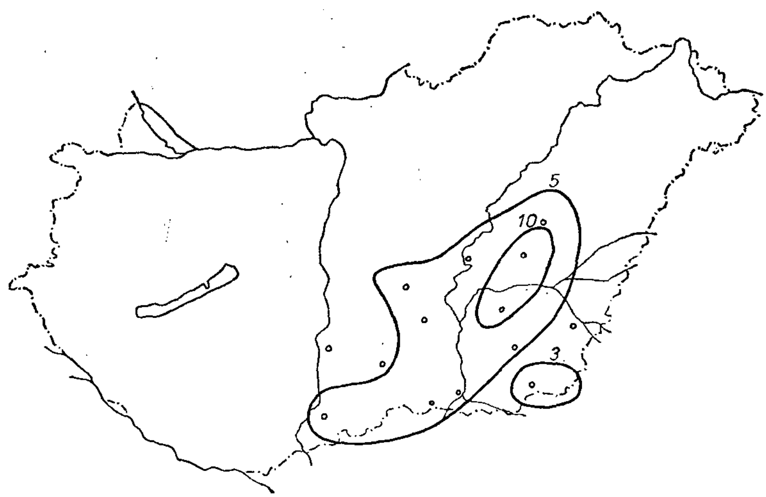

Fig. 18. The relative frequency (%) of the soil water content less than 50% of the available water capacity, 1931—1980, summer half-year

we can expect years with close to average but a little lower level of precipitation. (It must be noted however that we have to handle this type of tendency prediction carefully. The reason of it is that we can only take into consideration a substential but limited amount of reasons causing the change of a given meteorological parameter. The reliability of prediction would be greatly increased if we knew the physical origins, periodicities of the climate and we could explore their possible relations to the circulation of atmosphere.)

The next step was to examine these climatological factors in connection with some most important plant cultures. Since the regional distribution of the 14 involved stations in the four Great-Plain counties (Bács-Kiskun, Békés, Csongrád and Szolnok) is more or less uniform, and as the statistical information basis is similar, we correlated the above mentioned climatological factors to the average yields of these counties. We analyzed the time series of the average yields between 1960—83 (24 years). The examined plants were: wheat, corn and sugar-beet. The reason to choose these plants is that the 33,0% of the country's wheat producing fields and 33,6% of the country's total production of wheat belong to this territory and also the

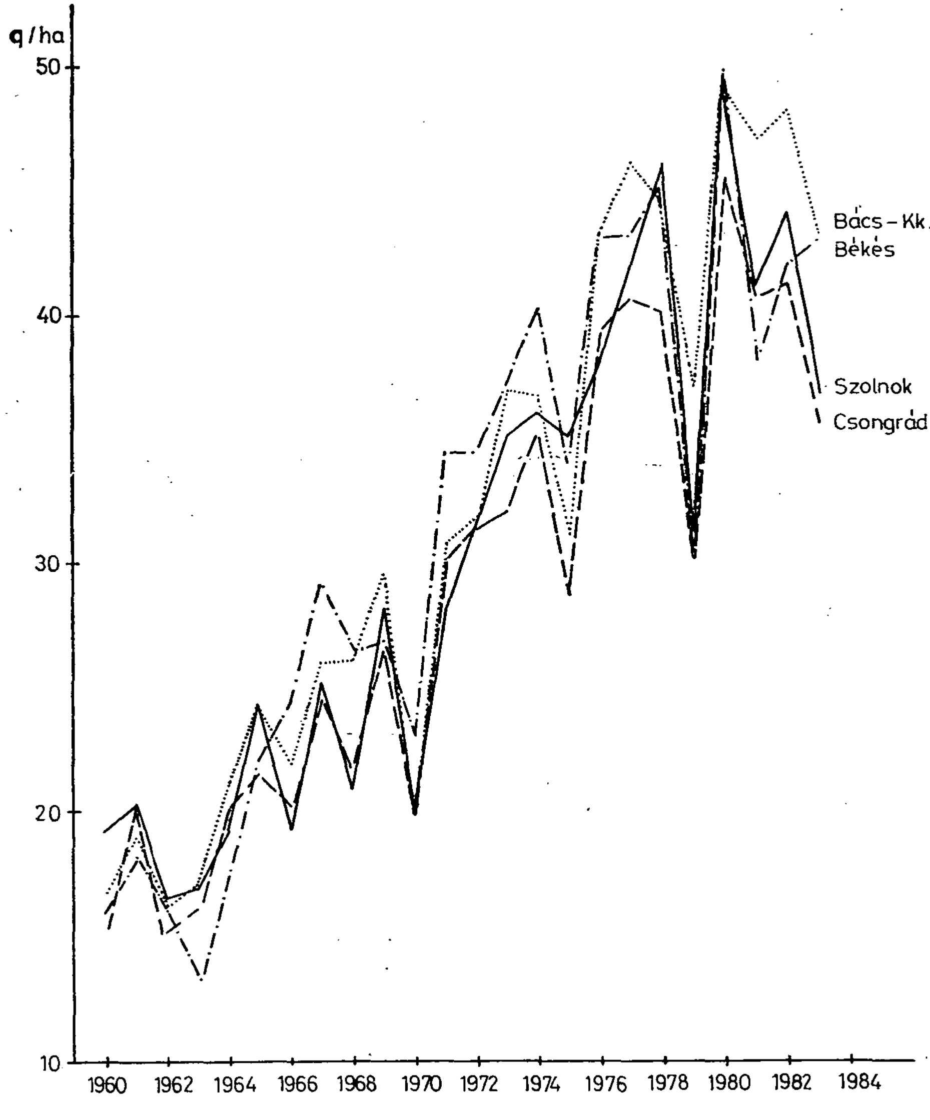

Fig. 19. The county average yeald of wheat (q/ha)

30,7% of corn fields and the 30,3% of corn yield comes from here whereas 40,1% of sugar-beet fields and the 39,1% of production come from these counties. At the same time only 31,2% of the country's total tillage land can be found here while it has only 29,2% of the total agricultural territories.

In the following we present the time series of the county-average yields of wheat, corn and sugar-beet, respectively *(Figs, 19, 20, 21)*. The figures show that the weather dependence of these plant cultures in these territories is similar to each-other. It is interesting however that the variance of these yields ($R_{max}-R_{min}$) which is characteristic of the weather dependence shows significant deviations from county to county. While for instance in the case of wheat the variance caused by the weather dependence is the biggest in Bács-Kiskun County (R=36,2 q/ha), it is the biggest for corn in Békés county (R=53,2 q/ha), and for sugar-beet in Csongrád county (R=261,0 q/ha). The high value of these parameters also show that the climate

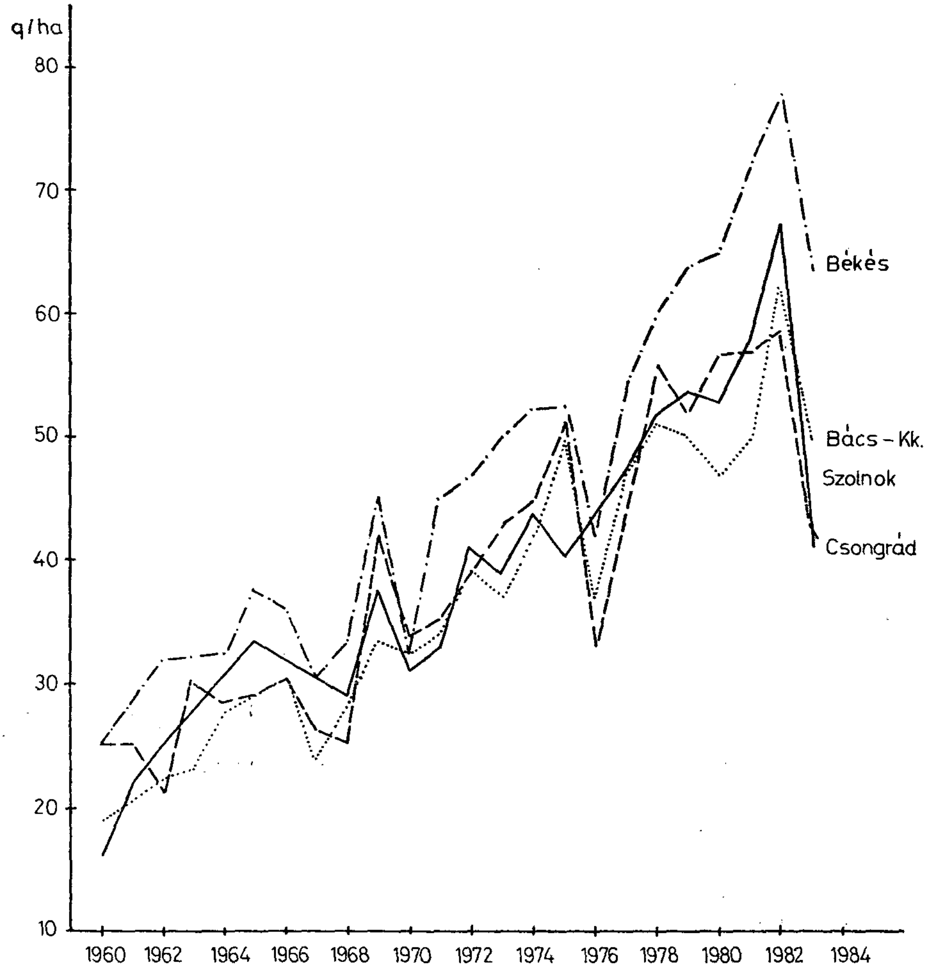

Fig. 20. The county average yeald of corn (q/ha)

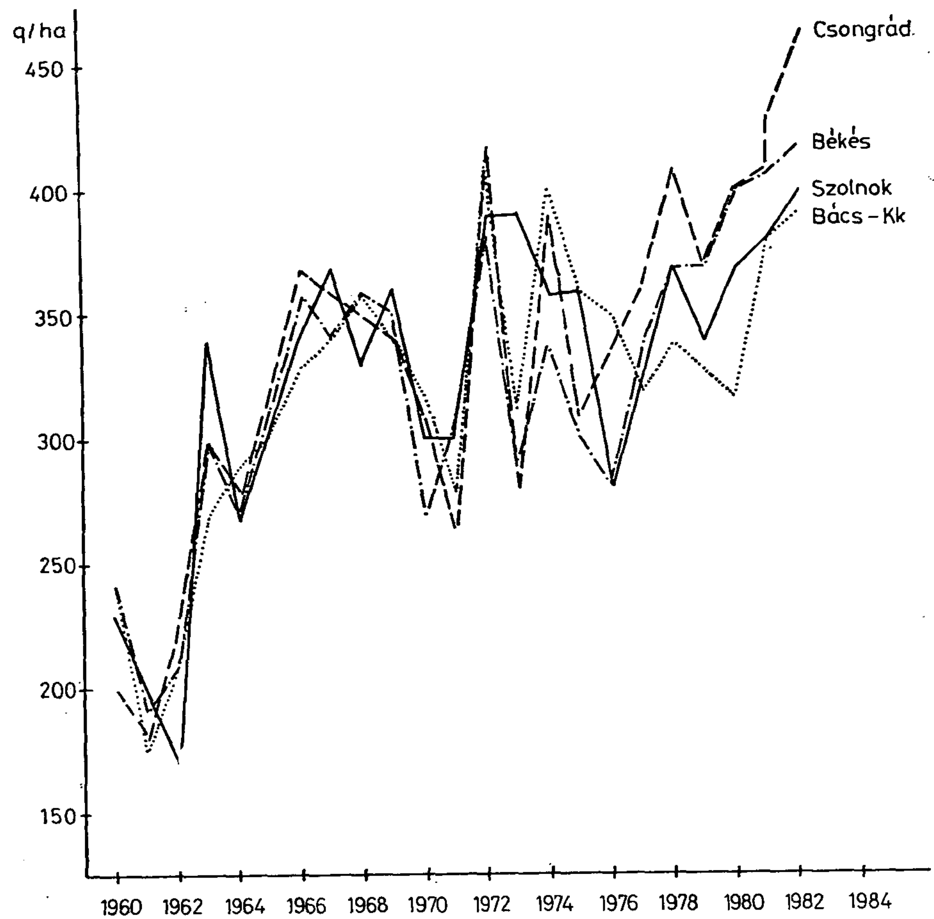

Fig. 21. The county-average yeald of sugar-beet (q/ha)

factors also play a crucial role in the development of yields even among today's modern agrotechnical circumstances.

During our studies we compared the yields to the total amount of precipitation of the summer season. Our investigations involved the precipitation dependence of the yields of corn and sugar-beet. On the basis of the 24 years long time series between 1960—1983 we can conclude the followings. The correlation coefficients between the yield of corn and the total precipitation of the summer season are as follow:

in Bács-Kiskun county	0,0727
in Békés county	0,2458
in Csongrád county	0,2558
in Szolnok county	0,3403

It is only in Szolnok county where we obtained a real precipitation dependence in the case of corn *(Fig. 22)*.

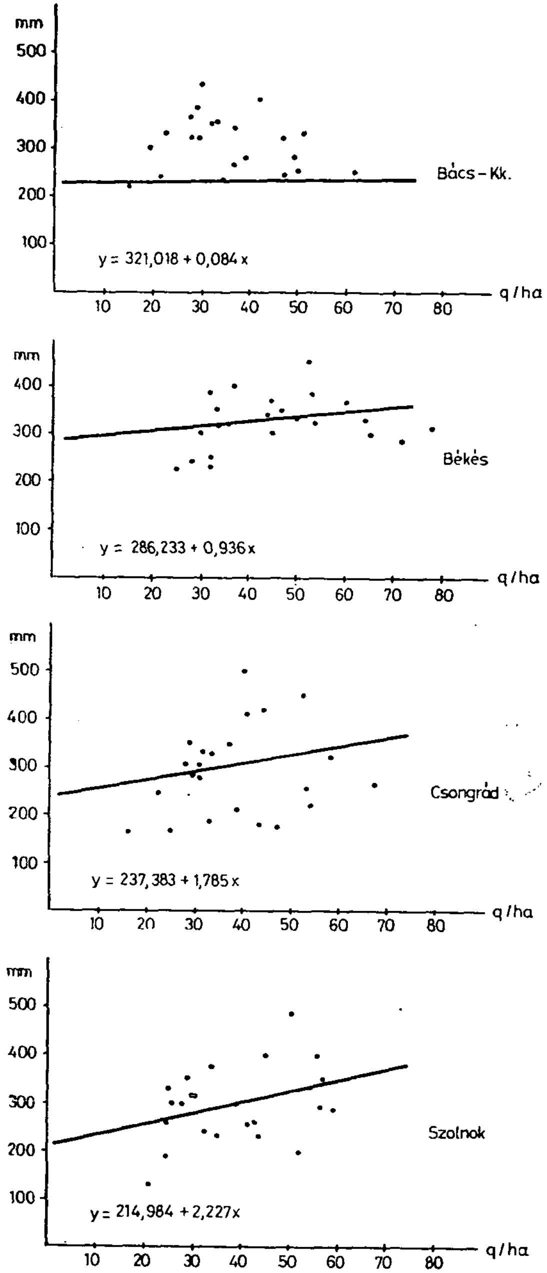

Fig. 22. Connection between the county-average yealds (q/ha) and the summer half-year precipitation totals (mm), corn, 1960—1983

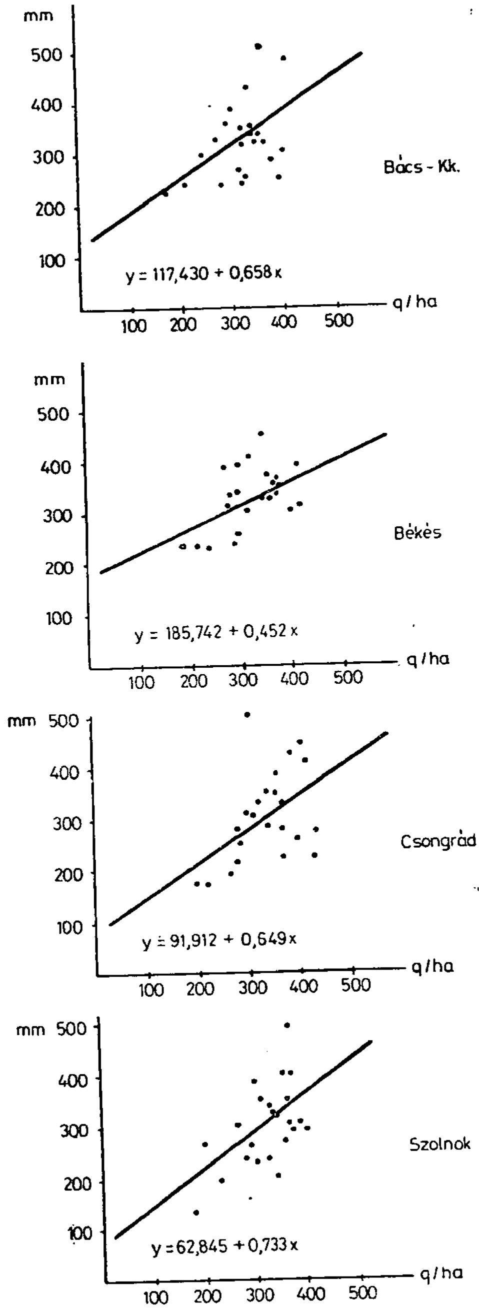

Fig. 23. Connection between the county-average yealds (q/ha) and the summer half-year precipitation totals (mm), sugar-beet, 1960—1983

The correlation coefficients between the yield of sugar-beet and the total precipitation of the summer-season are as follow

in Bács-Kiskun county	0,5010
in Békés county	0,2665
in Csongrád county	0,5263
in Szolnok county	0,5545

It is evident from the time data sets that in the case of sugar-beet the total summer season precipitation plays a crucial role among the different natural factors in the variation of yield *(Fig. 23.)*, whereas in the case of corn the summer season rain is not exclusively determining. It is well-known that corn is especially sensitive to the great fluctuations of temperature.

In summary we can conclude that the amount of precipitation in the Southern Great Plain — although it is rather changeable in space and time — ends with a negative balance each year and in extremely arid years it has a half-desert character. The changeable water supply is strongly reflected in the variation of the soil-water content as we can expect maximal water saturation also in the summer season but from the middle of the summer the low level of water content causing aridity is more and more frequent. We can also conclude that despite of the improving quality of agrotechnics the dependence of the yield of the studied plant cultures on the natural factors shows still very significant deviations. We can emphasize that the yearly repeating long-lasting lack of water showing regional variations must be retrieved by irrigation. In order to compensate the dry periods which are rather frequent according to our studies and to improve the inclination of cooperatives to irrigate the economical regulations can also be used (much improvement has been made in this direction in 1984).

Because of the complexity of the subject we could only discuss some of its aspects but these seem to be enough to draw the following conclusion: the cooperatives must build their own reliable irrigation facilities in the future.

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ON THE ANALYSIS OF SALT DYNAMICS ABOVE THE CRITICAL GROUND WATER LEVEL

by

M. Dzubay—*J. Juhász*

Adatok a kritikus talajvízszint feletti sómozgás vizsgálatához. A szerzők helyszíni megfigyeléseiket a száraz és öntözött viszonyok között a Tiszántúl északkeleti részén a szolnoki löszhát peremén végezték. Közelebbről az előbbiek Karcag, az utóbbiak pedig Kisújszállás városok határában folytak.

Száraz gazdálkodás esetében a „kritikus mélység" körüli talajvízszint-állás körülményei között — mint általában éghajlatunk alatt — kísérleti területünkön is a talajsók vándorlása az évszakonkénti szakaszosságot — a téli kimosodási és a nyári felhalmozódási irányzatot — követte.

Az elszikesedés veszélye nélkül öntözni lehet akkor is, ha a talajvíz a kritikus szint körül van, amennyiben gondoskodás történik arról, hogy a felesleges víz — talaj- vagy öntözővíz — elvezetést nyerjen. A dréneket ilyenkor megfelelő kiképzés esetén öntözésre és vízelvezetésre, lecsapolásra — tehát reverzibilisen — is fel lehet használni.

The autors field studies were made under dry and irrigation conditions in the northeastern part of Tiszántúl at the edge of the loessial plain of Szolnok. More exactly the first conditions were studied in the vicinity of Karcag, the latter in the vicinity of Kisújszállás.

In the case of dry farming, under conditions of ground water level around the "critical depth", as is usual in our climate, the migration of the soil salts followed the periodicity of the seasons — the trends of leaching in winter and accumulation in summer also in the area investigated.

It is possible to irrigate without risk of alkalinization also when the ground water level is near the critical level if we make sure that the superfluous water — ground water or irrigation water — can drain off. In such circumstances the drains can be used in case of suitable transformation, for irrigation and drainage, i. e. also reversibly.

Depending on the mechanical structure of the soil and the salt content of the ground water, evaporation can be fed already from the water table between 1 and 3.5 depth. In this case concentration of the salts dissolved in the water may alkalize the soil and cause accumulation of the salts (c, d, e).

The depth, from which the water-soluble salts can reach or approach the soil surface by capillary lift and can accumulate causing alkalinization of the soil as a result of evaporation, is called "critical ground water level".

Our field studies were made under dry and irrigation conditions in the northeastern part of Tiszántúl, at the edge of the loessial plain of Szolnok (a). More exactly, the first conditions were studied in the vicinity of Karcag, the latter in the vicinity of Kisújszállás.

The observation dealt with

1. the influence of climatic factors (precipitation, evaporation, irradiation, etc.) on the migration of the soil salts;
2. movements of the ground water as a factor of the migration of the salts;
3. the influence of human activity, such as irrigation.

Investigation Strategy

The investigations were carried out at two locations: one of them was unirrigated virgin grassland, the other irrigated plowland; the first had acidic alkali soil, the latter meadow soil, saline in depth. At different times — chiefly in spring, summer and fall — soil samples were taken from every 10 cm of the soil profiles. Profile sampling was repeated 3—8 times and the total salt percentage content of the samples was determined. The natural factors (precipitation, evaporation, ground water level) and human interference were evaluated mathematically and statistically.

With the aid of obeservation wells correlations were sought between the periodical variations of the water level and the migration of the soil salts.

Analysis of the total salt on the basis of electric conductivity was made according to our methodological manual.

As we have mentioned, the area investigated lies in the northeastern sector of Hungary. It is uniform both geographically and climatically, and it represents the regions with the most extremely continental climate in this country.

In the evaluation of the climatic elements we generally took periods of 25 years into consideration.

The area receives an average annual total of 2000 *sunshine* hours, and occasionally more. Farther north in the region, the annual total sunshine hours is already under 2000. Thus the average of the sunshine hours in the southern parts of the area is slightly higher than the average of the whole country. The average annual *total solar radiation* in the area is around 100 Kcal cm^{-2}.

The temperature conditions of the area are very extreme: the winter is cold, the summer is — except on the northeastern edges of the area — warmer than the national average. In winter severe frosts are frequent here, as the mean temperature in January varies between −2.5 and −4.0 °C.

The average of the annual temperature minima varies between −19.0 °C and —22.0 °C, but occasionally 10 degrees lower temperature also occur. The summer is moderately warm. The average mean temperature in July is 20—22 °C. In spite of this, warming up is intense in places, especially in the area investigated, where the average of the annual temperature maxima is around 35 °C.

The wind conditions of the area are very changeable. The annual average wind velocity is 2—3 m/sec. The annual average of windstorm hours varies between 145—180. In the southern parts of the area only 20—25 stormy days are likely to occur on average.

Fog formation is fairly frequent in the region, especially in its northeastern parts. In its southern parts, however, only 30—40 foggy days are likely to occur in a year.

Precipitation in the area is scanty. The average annual total precipitation varies between 500—550 mm. Near to this area lie the driest regions of the country: the area of the Hortobágy, the area between Szolnok and Szarvas, and the environs of Kunszentmárton. In these areas the amount of precipitation often does not reach even an annual 500 mm average.

The annual average number of rainfall hours is 1300—1800 in the area investigated. On the basis of the average of 50 years (1901—1950) — considering the monthly and annual amounts of precipitation at any one of the observation stations near to our area — we come to the conclusion that in the annual variation two waves can be observed: the maxima of May-June and October-November on the one hand, and the minima of January-February and August-September on the other. This regularity does not appear in every year becuse the distribution of precipitation in time and space is unstable and there is considerable fluctuation in the extreme values.

The soil temperature are also very extreme. In winter they are very low, in summer very high. Frosts are common in the winter. The mean soil temperature in January varies between −3.0 and 0.1 °C at 2 cm depth.

In summer, the surface of the soil is warm. The mean temperature in July at 2 cm depth under the soil surface is between the yearly average, 33.4 °C and 29.8 °C.

The migration of salts under dry conditions

The migration of the soil salts in the area under conditions without irrigation follows, as is usual in our climate, the seasonal periodicity of leaching out in the winter, and moving upward in the summer. In normal weather conditions these natural processes lead to washing down and sinking of the maximum salt accumulation in winter. As can be seen in *Fig. 1*, the maximum accumulation of salt in profiles 158 and 159 is at 70 cm, and in cores 158 and 159 at 80. (Sampling of 15 Dec. 1972. Continous black line.)

Owing to the rise in temperature, evaporation of the ground water, and other causes, the direction of the migration of the salts changes and turns upward in the spring. As a result, the maximum accumulation of salts appears at 60 cm in the core samples (*Fig. 1.*; observations on 5 April 1972 and 9 April 1973; dot-and-dash line and continuous line).

During the summer, the upward migration of the soil salts is more intense due to increased evaporation. It is generally at this time of the year that the migrating salts rise and come nearest to the soil surface. In the first core (156, 157) their distance from the surface is 50 cm. In the other, the maximal accumulation does not shift, but the salt curve (*Fig. 1.* 25 July 1972; dotted line) comes nearest to the soil surface at this time. The abstacle to further rising of the salts was that before sampling 70 mm rain fall in the area *(Fig. 2),* which caused the water-soluble salts of the different kinds of alkali soils to perform a different migration [f]. In fall, with the coming of steady rains, the prevailing direction of the salt migration changes: the salts begin to migrate downward, that is, the process of migration is repeated. The winter period begins again.

Under conditions without irrigation, the migration of the salts depends mainly on three factors: 1. precipitation, 2. evaporation, and 3. the depth of the water level. Naturally, the quality of the soil and the temperature are also important factors.

If the level of the ground water is lower, then the leaching effect of precipitation prevails. In the contrary case, however, when the ground water level is high, the situation is reversed. The high ground water level is summer, owing to increased evaporation, favors the migration of the salts upward.

With a view to studying the salt migration, we made three wells for the observation of the ground water level at Karcag, near to the area of the investigation, in the vicinity of borings 156—159. Besides these, on two occasions, in the summers of 1971 and 1973, we made three parallel borings down to the ground water level. The percentage of the total salt content of the soil samples was evaluated, and the data are shown in *Fig. 1.*

In these wells the water level was around 2 m depth during the five years of observation. The seasonal variation and the large amount of precipitation were regularly observed. Small differences were observed in the height of the water levels,

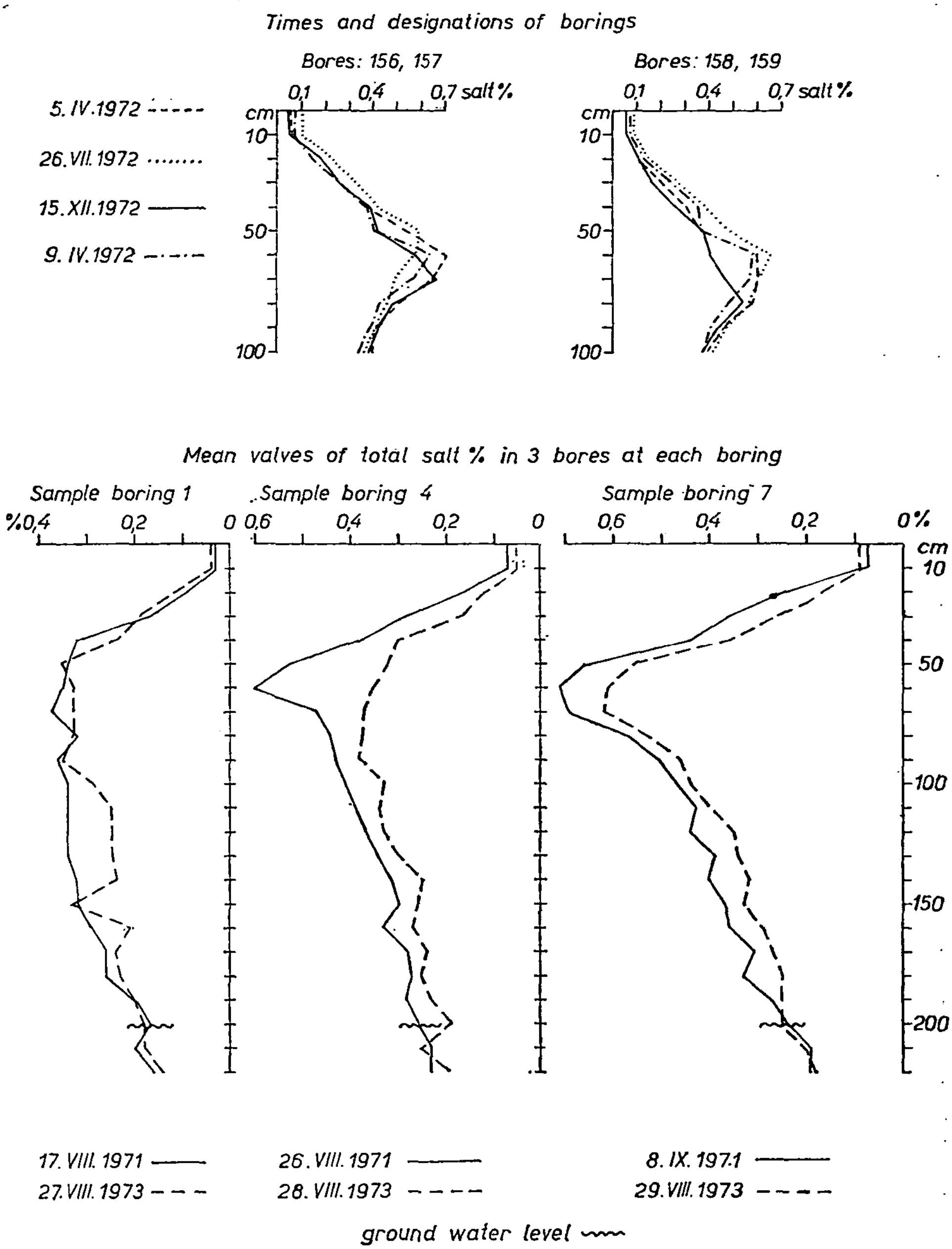

Fig. 1. Mean values of total salt percentage

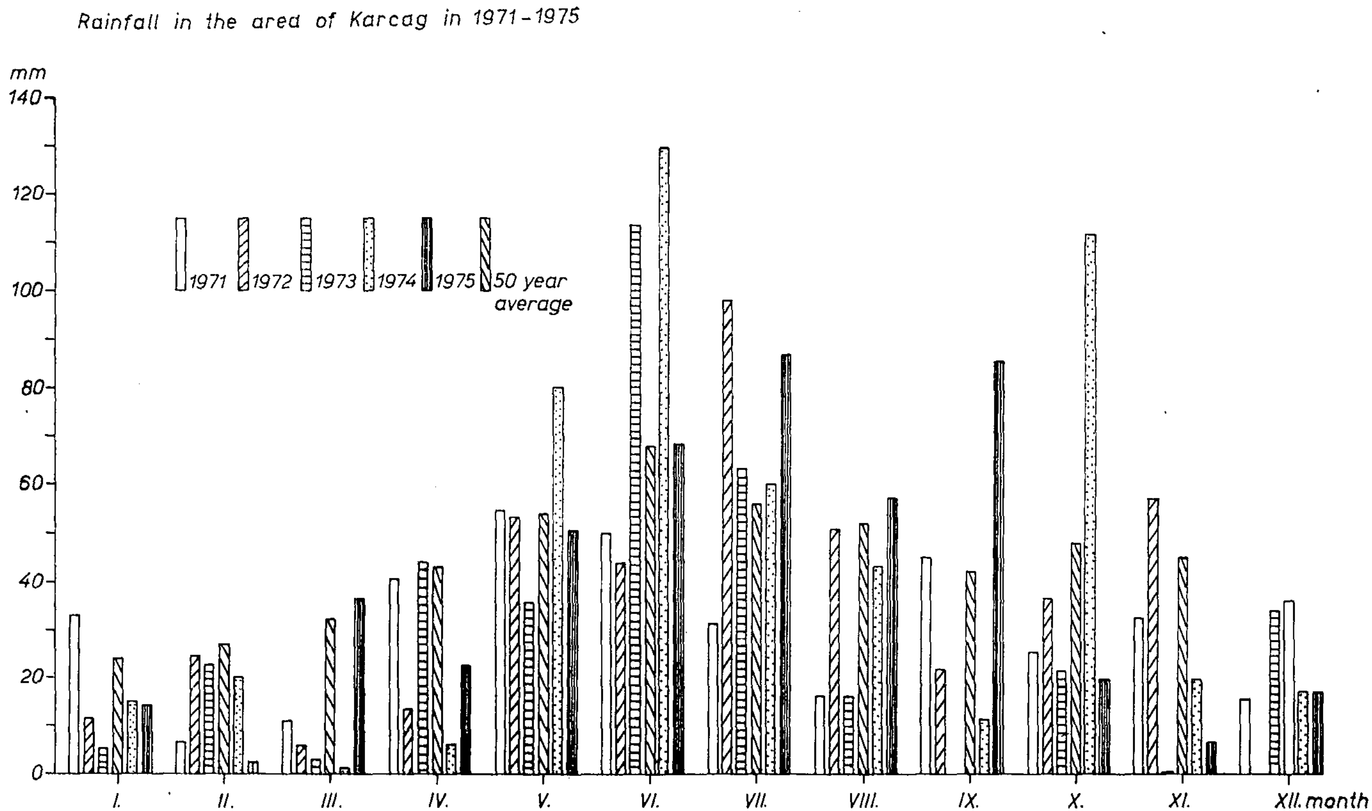

Fig. 2. Rainfall in the area of Karcag in the years 1971—1975

which can be explained by the different mechanical structures of the soil layers feeding the wells.

We noted the following correlations between the salt migration shown by the upper line in *Fig. 1* (bore 156—159) and the variation of the water level in the observation wells: On 26 July 1972, at the time of high water level in the wells [f], the salts were at a high level (dotted line) in the soil profiles (156, 157, 158, 159). In winter, on 15 December at the time of low water level, the salts were at a greater depht (continuous line in *Fig. 1*). In spring, on 5 April 1972 and 9 April 1973, the salts were at mid height between the two water levels previously mentioned. (*Fig. 1*, dotand-dash line and continuous line.) From this it is clear that the seeping of the water in the wells and the maximum accumulation of the soil salts are synchronal.

On two occasions we made three borings down to the ground water level beside each one of the wells *(Fig. 1)*. Soil samples were taken from the boring at avery 10 cm and from the total water-soluble salt content was determined. The mean values of the comparable data were calculated and are shown in *Fig. 1*. In the course of the statistical calculations we found significant leaching of the salts only in one case, beside well 4, above the capillary zone. Near the other two wells we found only salt migration, a leaching tendency in the profile (well 7), or not even that (well 1). We emphasize this because between the mean salt values in the case of the tendencies the statistical standard deviation of the heterogenity of the soil and the analysis is greater than the differences between the samples taken at two different times. Yet a definite decrease can be seen.

Salt migration under conditions with irrigation

In this case the migration of the soil salts during the irrigation period is influenced — depending on the method of irrigation — first of all by the irrigation water. However, in this case, too, the natural conditions, such as precipitation, temperature, the chemical and physical structure of the soil, play an important role. We can see this in the following.

We carried out investigations of these factors in the vicinity of Kisújszállás. The soil of the area is saline in depth, with a moderately thick humus layer, and in dapth carbonate-containing meadow clay. The 0—60 cm top layer was analyzed. The plant cultivation experiment of *J. Kapocsi* [g, h] was going on in the area. He was using modified furrow irrigation.

In the study area, during two vegetation periods (1974, 1975), on two occasions in each, before and after irrigation, among the furrows and beside them, we made 16 soil borings 60 cm deep in each place. The soil samples were taken from each 10 cm. After this, the total water-soluble salt percentage was determined on the basis of electric conductivity in our laboratory. The samples taken parallelly were suitably grouped and statistically evaluated. The results are shown graphically in *Figs. 4.* and *5.*

The area was drained at right angles to the furrows 45—50 cm deep at 60 cm intervals. The drain diameters were 8 cm [h].

We must mention that in the period studied, during the vegetation periods of 1974 and 1975, the weather was not very favorable for the analysis because of heavy rains *(Fig. 3)*; in fact it disturbed our analysis bacause it caused strong leaching of the soil with humid conditions, which were very different from the average conditions of many years.

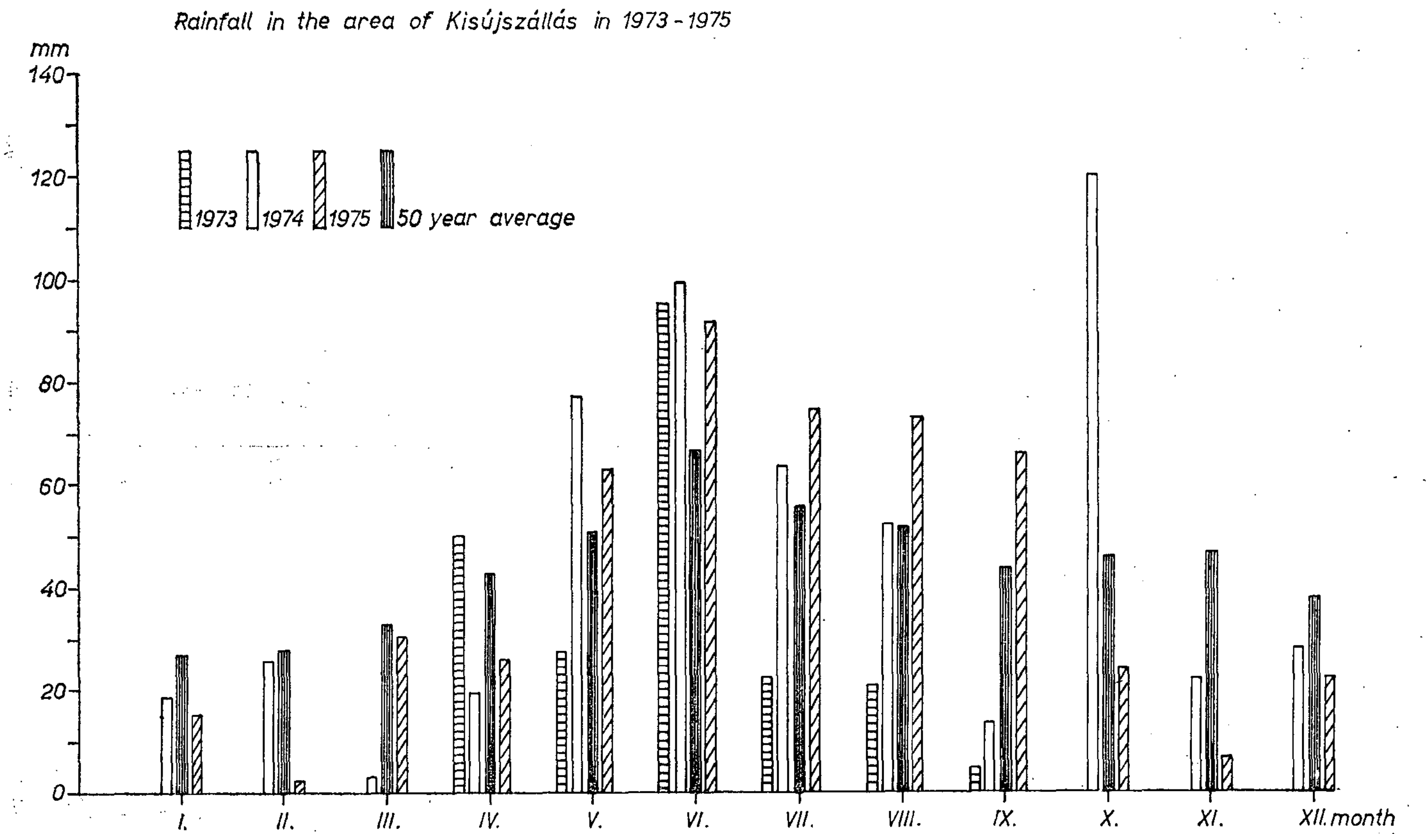

Fig. 3. Rainfall in the area of Kisújszállás in the years 1973—1975

In the course of 1974 the disturbance was first of all due to the extreme amount of rainfall in October *(Fig. 3)*. Under normal weather conditions the downward migration of the soil salts usually only just starts in this month. In this case, however, the intensive and significant downward migration of the soil salts, usually to 40 cm depth, had already occurred in the immediate vicinity of the irrigation furrows and among them as well in the whole experimental area. Significant leaching down to 30 cm depth at a 0,1 or 1% level was recorded only on one occasion (*Fig. 4,* last graph). Then the effect of irrigation or of the summer soil humidity manifested itself only as a tendency in evaporation, in the upward salt migration, in the higher water-soluble salt content, especially in the 50—60 cm layer *(Fig. 4)*.

The salt migration data are generally significant at 0,1 and 1% levels. The most unfavorable significant difference is 5%, when its value is 0,04 total salt per cent *(Fig. 4)*.

In 1975 the amount of rainfall in the period of April through October was about 5% less, and its distribution more even than in the previous year *(Fig. 3)*. This mani-

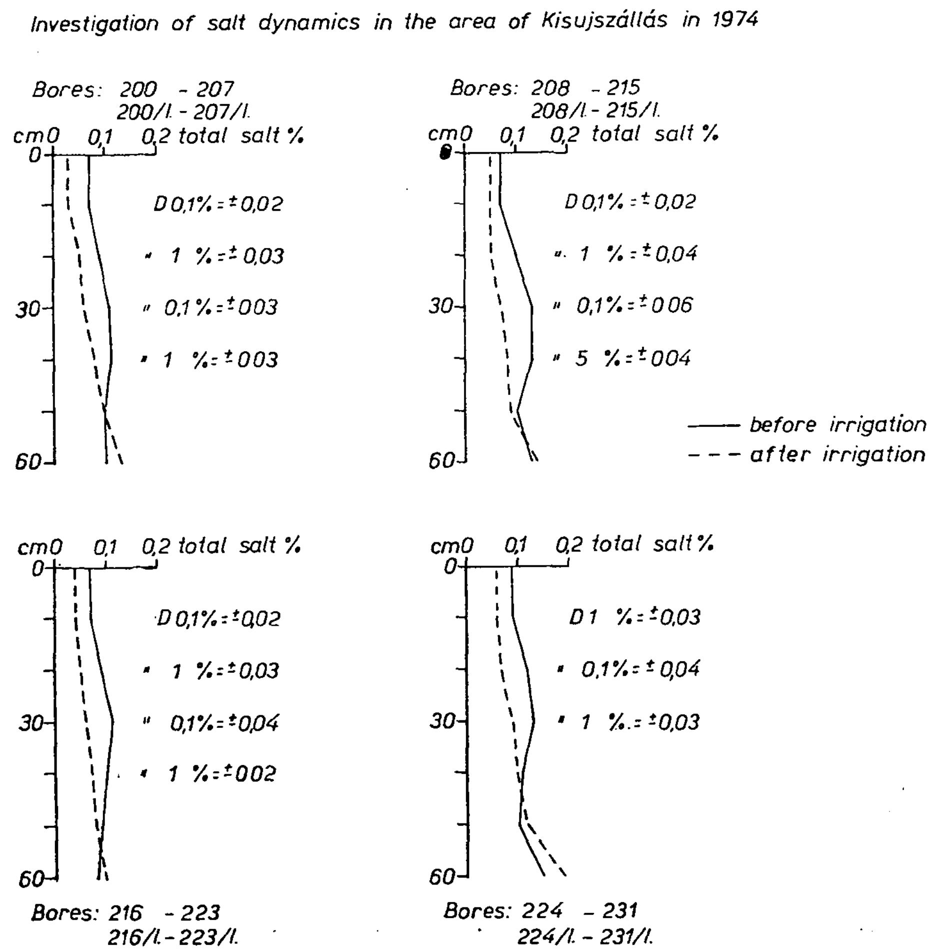

Fig. 4. Investigation of salt dinamics in the area of Kisújszállás in 1974. D=difference significant

fested itself in leaching and a higher salt content of the soil profiles *(Figs. 4 and 5)*. In comparison with the situation before irrigation, the data were significant less frequently and to a lesser degree *(Fig. 5)*. This phenomenon (the significance) can be explained by the considerably more humid March of 1975 *(Fig. 3)* and the higher degree of leaching of the soil profiles which served as the basis of comparison *(Fig. 5*; continuous line).

On the basis of the foregoing we can state that if during, before, or after the vegetation period there is more precipitation than the long-term average, irrigation (drains combined with irrigation furrows) causes no salt accumulation in the surface soil even when the stickiness of the meadow clay is 75—80.

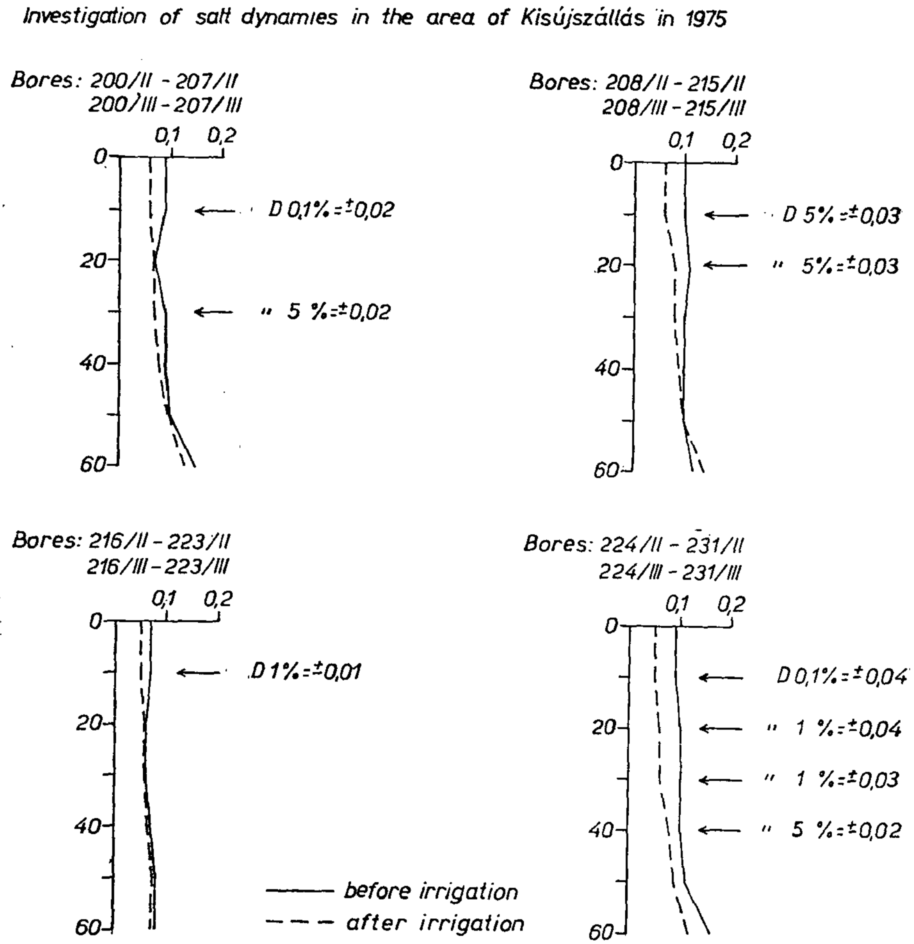

Fig. 5. Investigation of salt dynamics in the area of Kisújszállás in 1975. D=difference significant

Conclusions

In the case of dry farming, under conditions of ground water level around the "critical depth", as is usual in our climate, the migration of the soil salts followed the periodity of the seasons — the trends of leaching in winter and accumulation in summer also in the area investigated. This regularity was the more apparent the deeper the ground water level lay or within certain limits the more alkalizable the soil was.

The water level near the "critical depth" controls the salt migration in the surface soil according to the rainfall and evaporation. Then the case of high ground water level, the maximal salt accumulation lies higher, in the case of low ground water level it lies lower.

Under conditions with irrigation on highly sticky, in the subsoil saline meadow clay, in the case of drain and furrow irrigation — if in the vegetation period the weather is more rainy than the long-term average — no salt accumulation takes place in the surface soil.

It is possible to irrigate without risk of alkalinization also when the ground water is near the critical level if we make sure that the superfluous water (ground water or irrigation water) can drain off. In such circumstances the drains can be used in case of suitable transformation, for irrigation and drainage, i. e. also reversibly.

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THE ALTITUDE SYSTEM OF RAINFALL IN THE MÁTRA HILLS

by

B. Roncz

A csapadék magassági rendszere a Mátra hegységben. A tanulmány a tengerszint feletti magasság és a csapadékmennyiség összefüggését vizsgálja a Mátra-hegység területén. Megállapítja, hogy ez az összefüggés tavasszal és ősszel szorosabb, mint nyáron és télen. A számított és a mért csapadék mennyiségének összevetésével meghatározza a Mátra orografikusan csapadékhiányos és orografikusan csapadéktöbblettel rendelkező területeit.

The study investigates the correlation between the height above sea level and the quantity of precipitation in the area of Mátra Hills. It points out that this correlation is closer in spring and autumn than in summer and winter. It determines the areas of Mátra Hills having orographically lack and orographically surplus of precipitation by the comparison of the quantities of the calculated and the measured precipitation.

The Mátra Hills is a part of the Hungarian Mountains of Medium Height. Its area is about 1000 km^2. Its extension can be decided by the following geographical coordinates: North Latitude 47° 40'— 48°10' (north-south extension). East Latitude 19°28'—20°25' (east-west extension). Its highest summit is Kékestető (1015 m).

It is a well-known fact that with the increase of the height above the sea level (to a certain height) the quantity of rainfall is increasing. The influence of the mountains made on the rainfall is caused by well-known physical reasons and regularities. In our paper we are going to reveal the relations between the height above the sea level and the quantity of rainfall referring to the Mátra.

The data of 64 rainfall-measuring stations found on the territory served as materials to our research with the rainfall-averages of 1949—78 among them. For 34 stations the whole 30 years series were at our disposal, while at the other 30 stations we found 10—19 years old (not full) series. So in the latter cases we considered reduced, 30 year-old averages.

The average height of the rainfall measuring stations is 300,1 m, its streoscopic position is shown on *Figure 1.*

Let us see on the hypsographical curve how the height of the examined area joins with the area itself *(Fig. 2)*. The average height of the examined area is 279,5 m, so the average height of the rainfall measuring stations is approaching this value, and the network of our stations gives representative data for the examined territory. We have examined the changes of rainfall according to height, its monthly averages in the function of height. On the basis of the data being available according to height levels we regard height an independent variable, while the quantity of rainfall a dependent variable. Representing the pairs of value in a system of co-ordinates, we receive the multitude of different points *(Fig. 3.)*

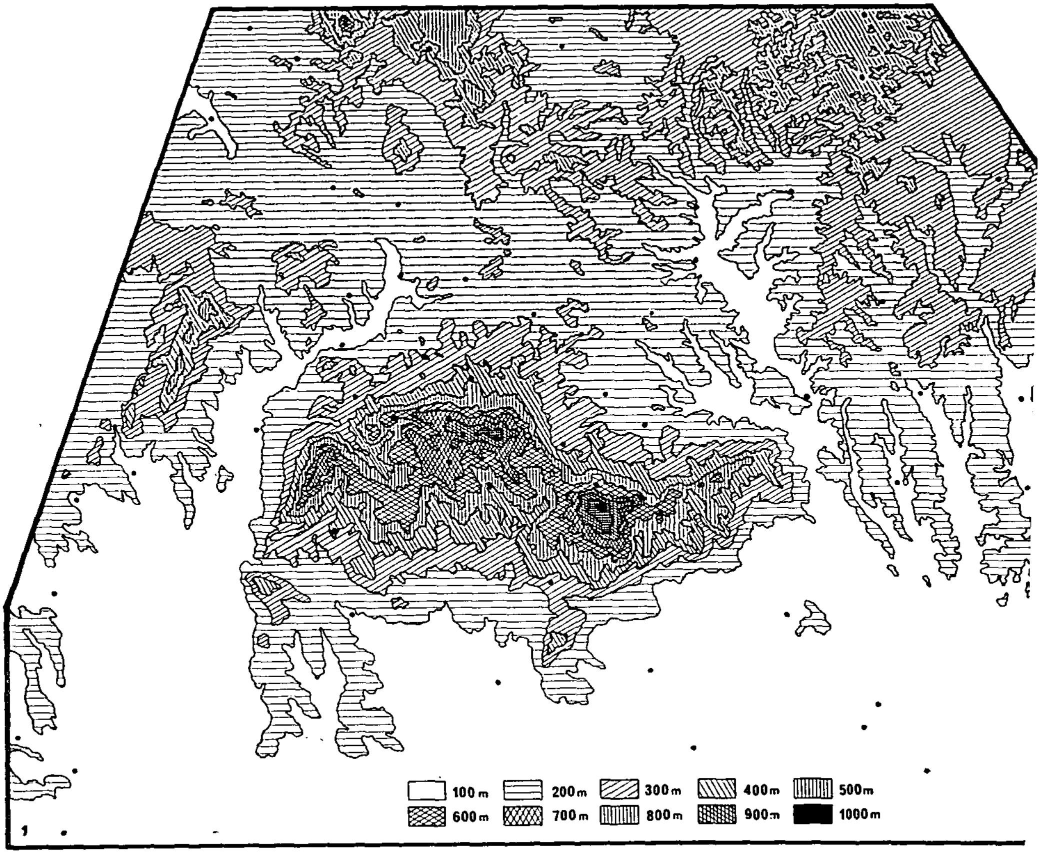


Fig. 1. Contour line map of the Mátra Hills with network of stations

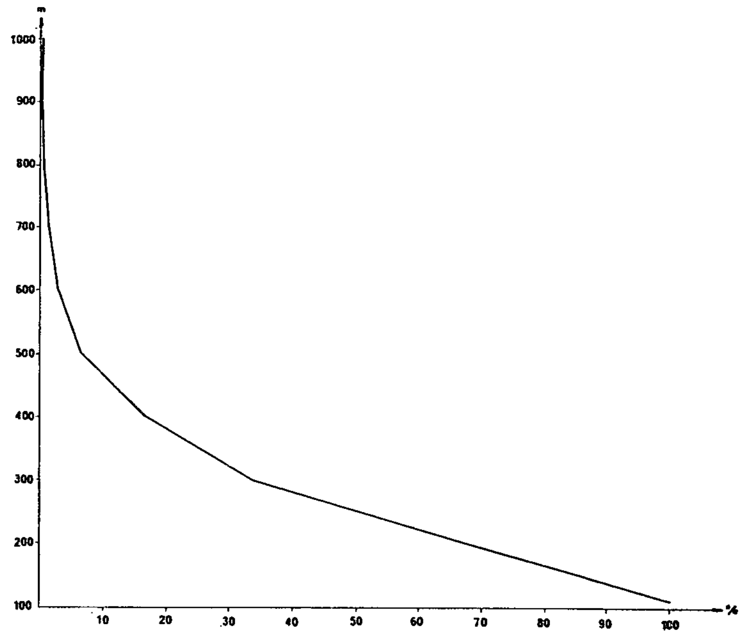
The relation shows an unambigously linear connection of stochastic character, which can be described with the following formula:

$$y = a_0 + a_1 x \tag{1}$$

y = quantity of rainfall x = height.

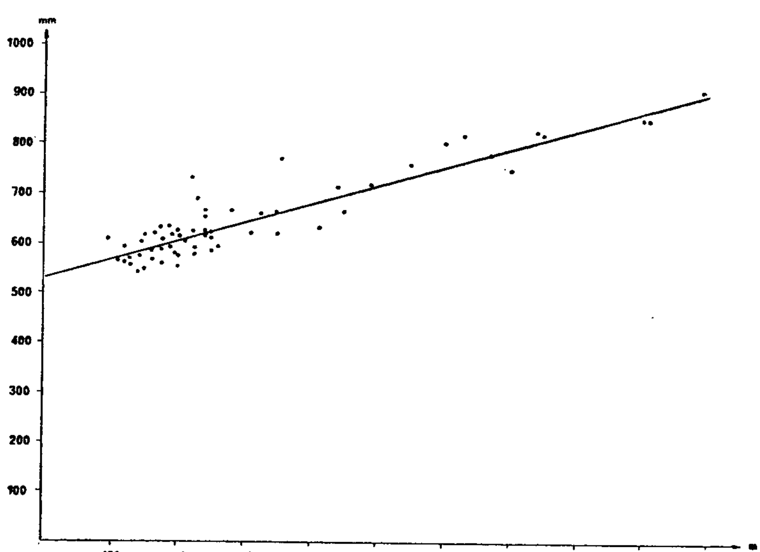
Determining the equation of the straight which approaches best the observed data the *Table 1* contains the constants in monthly, annual groups and according to the seasons of the year. We marked in it as well the co-efficient of correlation between the amount of rainfall and the height above the see level (r), and the territorial average of the rainfall (y) and its standard deviation (s).

Constant a_1 gives the increase of rainfall falling on the height, its annual way is shown in *Figure 4*. In the annual course of constant a_1 typical double wave can be observed. We distinguish a summer maximum (June, July) and an autumn secondary maximum, as well as a January minimum and a September secondary minimum. According to our assumption the annual course is influenced by two factors: the frequency of the average rainfall outputs and the average rainfall. The reason for the summer maximum is the fact that the one-day rainfall outputs are the greatest; the



2.

Fig. 2. Hypsographical curve concerning the Mátra Hills



3.

Fig. 3. Relation between the quantity of the annual average rainfall and the height above see level

Table 1

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	Spring	Summer	Autumn	Winter
r	0,787	0,783	0,901	0,922	0,893	0,837	0,669	0,625	0,795	0,888	0,839	0,777	0,919	0,933	0,799	0,892	0,801
a_0	29,94	30,18	25,02	37,18	52,33	74,00	59,98	59,93	37,88	35,43	47,36	44,26	534,57	114,53	193,58	120,55	104,23
a_1	0,019	0,023	0,026	0,035	0,039	0,043	0,042	0,025	0,019	0,029	0,038	0,028	0,367	0,101	0,109	0,087	0,070
$\bar{Y}$	35,6	37,1	32,8	47,8	64,2	87,0	72,7	67,2	43,7	442	58,8	52,5	644,6	144,8	226,5	146,7	125,3
S	5,2	6,3	6,2	8,3	9,6	11,2	13,7	8,4	5,3	7,1	9,8	7,7	86,3	23,4	29,7	21,1	18,9

maximum at the end of autumn is the result of the frequent rainy days, but the daily outputs are smaller. During the January minimum rainfalls are quite frequent, but the outputs are small. At the September minimum it is just on the contrary: the number of rainy days are less, and the daily outputs are bigger (at the same time they are smaller from the summer outputs).

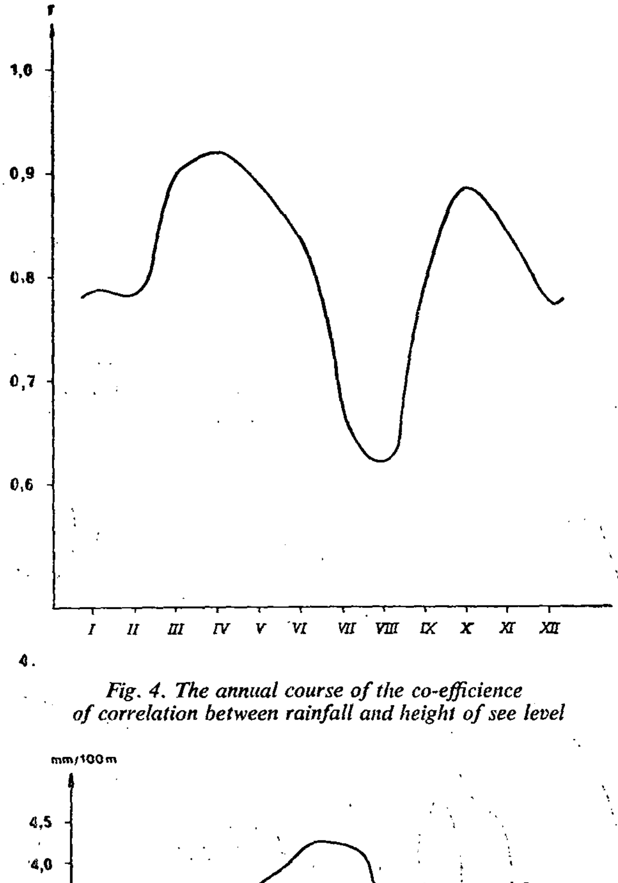


Fig. 4. The annual course of the co-efficience of correlation between rainfall and height of see level

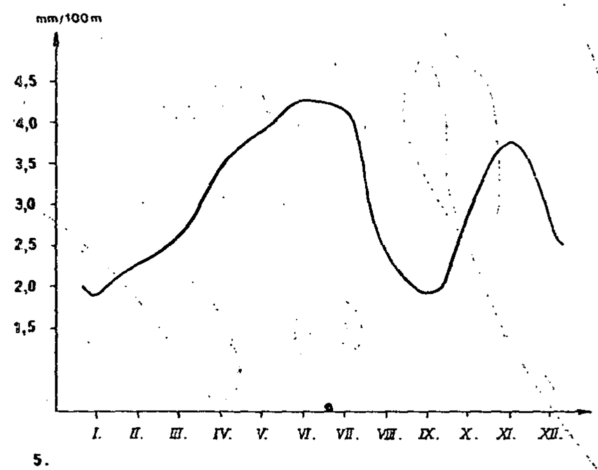


Fig. 5. The value of rainfall increase falling on 100 m height

Now we are going to examine what close connection exists between the rainfall and height on the basis of co-efficient of correlation *(Fig. 5)*.

Our figure demonstrates very well when is the rainfall-increase less close together with the height. The double wave is to be found at the co-efficient of correlation (r) just like as we hawe seen it at the representation of a_1 *(Fig. 4)*. The closest connection is experienced in spring and autumn, the loosest in summer and winter. The spring and autumn maximums, the closer connections are caused by the more equal dispersion of rainfall in the gliding up fronts and by the larger outputs (which are smaller in summer). The summer minimum that is to say the less closer connection between rainfall and height can be attributed to the fact that the dispersion of rainfall is capricious on the examined area (local rain-storms, showers). The discovery of the reasons for the the secondary winter minimum and the less closer connections requires further datailed examinations. Yet we can already as certain that even the less closer connections are real statistically.

An the basis of the above mentioned calculations we can state that 37 mm/100 m is the average height increase in the Mátra Hills at the annual ammount of rainfall.

For the practical application of our above expounded method we can draft a more datailed and precise plan of rainfalls, because with the help of this mathematical model we can draw up the datailed rainfall map of such areas where we have no rainfall map of such areas where we have no rainfall measuring stations with appropriate density. By interpolation the most probable rainfall quantity belonging to given heights can be determined.

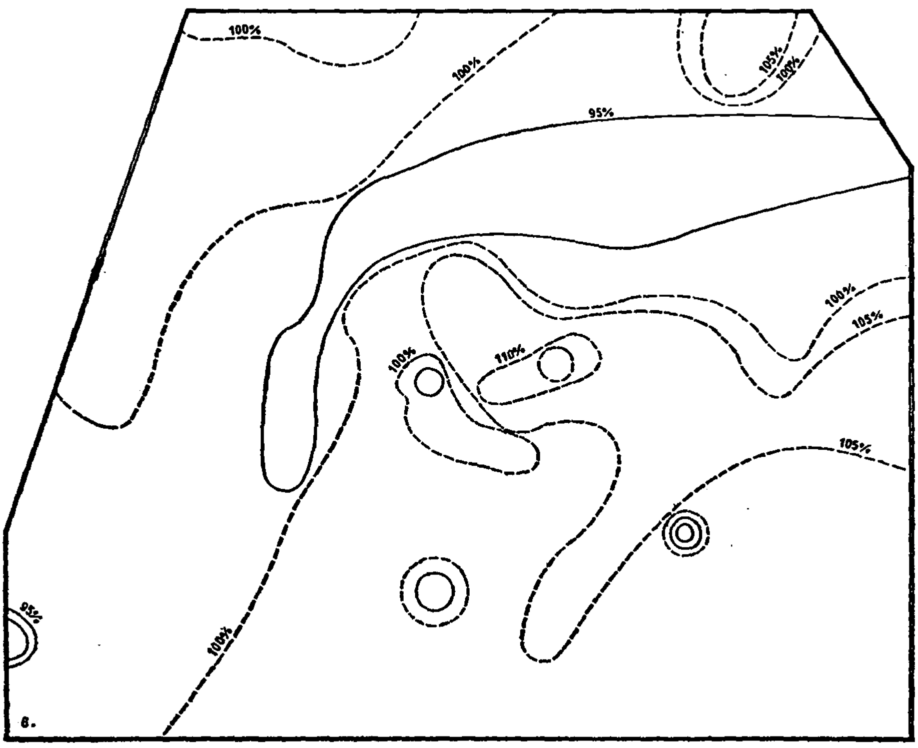


Fig. 6. Areas of orographical rainfall surplus and lack in Mátra — spring.

The Areas of the Orographical Rainfall Surplus and Lack in the Mátra Hills

We can determine the disperse of rainfall averages according to height on the basis of function No 1, that is to say the quantity of expected rainfall on a gived height above the sea level. Let this calculating value be C^x, and C is the really noticen rainfall (30 year old chief value).

The C/C^x quotient marks whether any examined station receives more rainfall or less than it would be suitable on the given height above its see level.

In case when $C/C^x > 1$, we can speak of *orographical lack of rainfall,* and when $C/C^x < 1$, of *orographical surplus of rainfall.*

Counting with the equation (1) we have determined the probable C^x according to height concerning the Mátra Hills by seasons, and then we have compared it with the real data (C). On the basis of C/C^x quotient we have marked the areas of the Mátra having orographical lacks of rainfall as well as surplus of rainfall according to the seasons of the year. The geographical dispersion of these values can be seen on *Figures 6—9.*

Their common feature is the change from season to season of the areas with orographical surplus of rainfall and lack of rainfall as well with their values. The difference is most striking between the winter and summer periods. But quite typical is the deviation between autumn and summer too. We can distinguish even such areas where the areas of surplus and lack of rainfall change places (for example in the

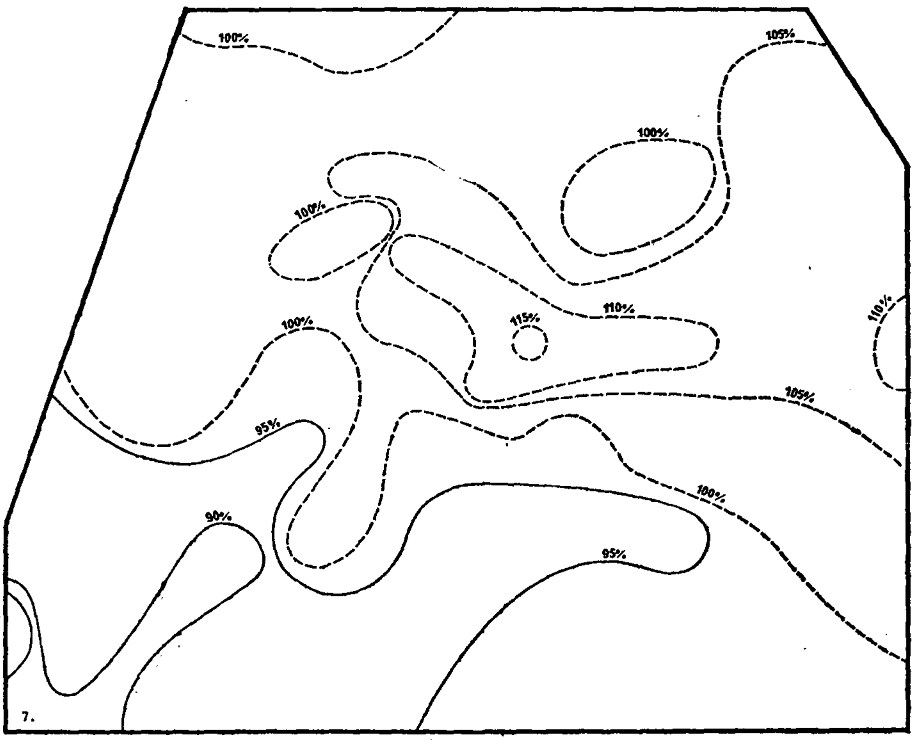


Fig. 7. Areas of orographical rainfall surplus and lack in Mátra — summer

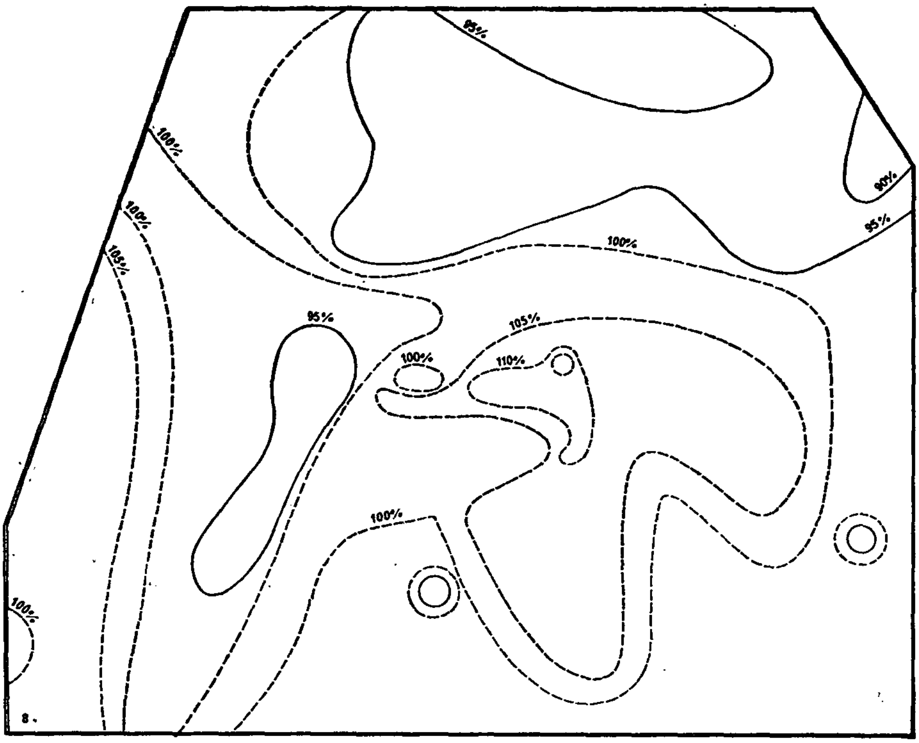


Fig. 8. Areas of orographical rainfall surplus and lack in Mátra — autumn

South-East of the Mátra surplus of rainfall can be observed in winter and lack of rainfall in summer).

The reasons for the basic deviations are to be found in the fact that the reigning air currents are changing by the seasons, and the character and structure of rainfall is different. During the winter halfyear the rainfall joins with the warm fronts (gliding up front) caused dominantly by the south air currents, while during the summer period it joins with the cold front caused by the North-West air currents. It is justified by the frequency of direction of winds as well *(Fig. 10)*.

The figures illustrate well that in winter the reigning direction of winds is that of South-South-West, while in summer that of North-West-North.

On this basis examining the lack or surplus of the orographical rainfall we can come to the following conclusion:

In that case when in winter a surplus of rainfall, and in summer a lack of rainfall appears on the given area, the rainfall relations of the area formally stand closer to the mediterranian type (*M*). On the other hand when there is a lack of rainfall in winter and a surplus of rainfall in summer, the rainfall relations of the area are much more similar to Continental climate (*K*). These relatively not great differences can be demonstrated in botanical associations from time to time *(Fig. 11—12)*.

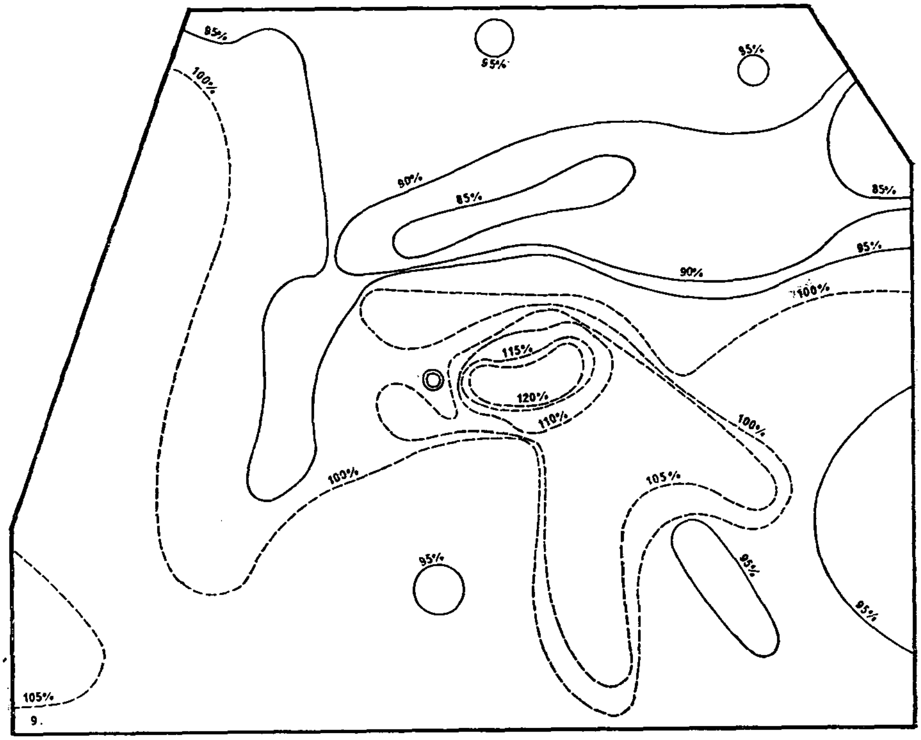


Fig. 9. Areas of orographical rainfall surplus and lack in Mátra — winter

Summary

In the first part of our paper we have examined the changes of rainfall according to height, and their monthly averages in the subordination of height. Having represented the data by levels being at our disposal in a co-ordinate system it can be stated that there is a linear relationship between rainfall and height. We have expressed it with the relation $Y=a_0+a_1x$. Substituted the measured data we have received the values of a_1 and a_0, as well as the value of the co-efficient of correlation (r) concerning the Mátra Mountains. Having represented them we have demonstrated that the relation between height and rainfall in the course of a_1 and the co-efficient of correlation is closest in spring and autumn, while it is the least closest in summer and winter.

In the second part of the paper we have determined on the basis of the calculations represented in part I how much rainfall can be expected at the given height above see level. On the basis of the quotient C/C^x we have determined the areas with the lack and surplus of orographical rainfalls of Mátra (where C^x is a calculated value, C — effectively observed rainfall), and tried to find explanations to the reasons of their formation.

A practical application of the method described in the paper can be used at making detailed plans of rainfalls in cases when we have no rainfall measuring stations at our disdosal with adequate density on a given area.

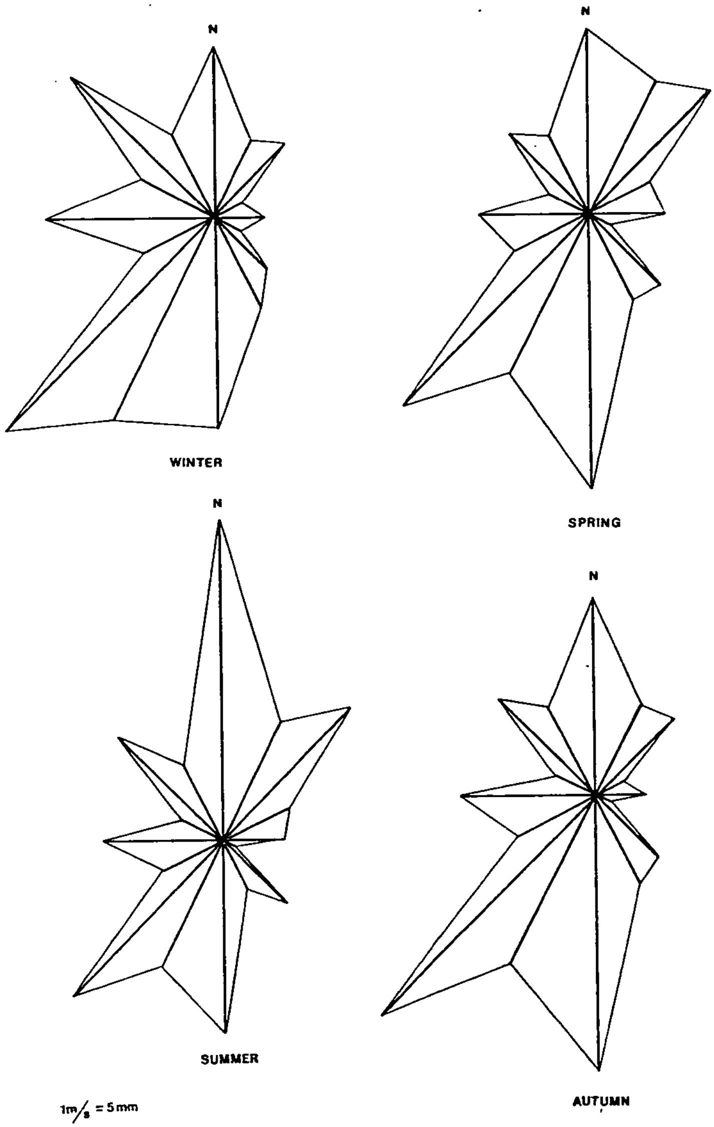


Fig. 10. Relative frequency of directions of winds at different seasons on Kékes-tető (calculating from 8 daily observations in 1975—79)

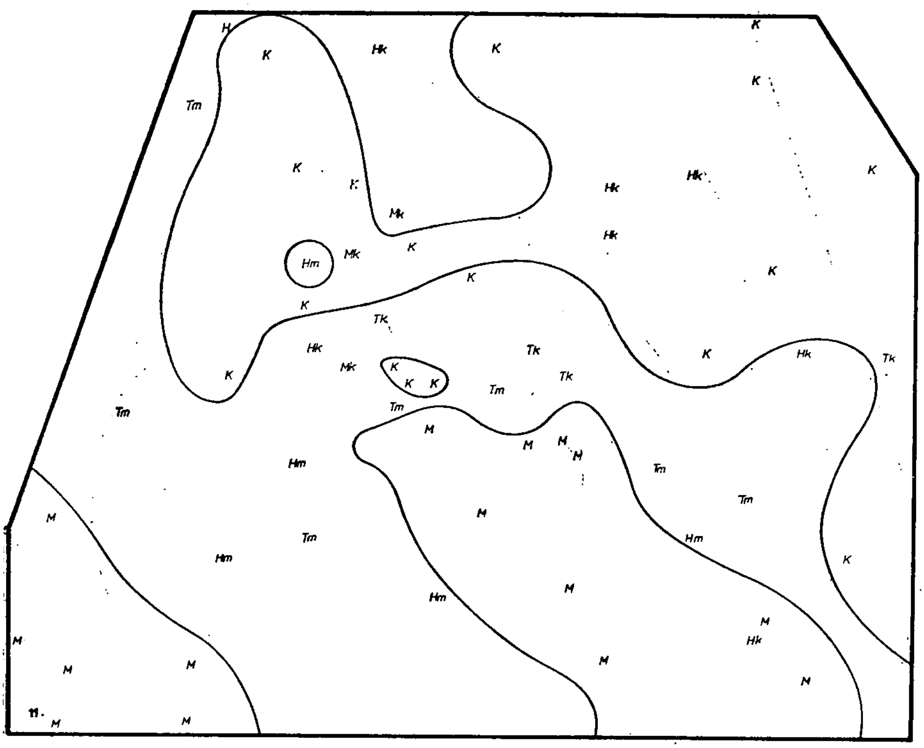


Fig. 11. Areas of Mediterranian (M) and Continental (K)-like rainfalls (in winter-summer relation)

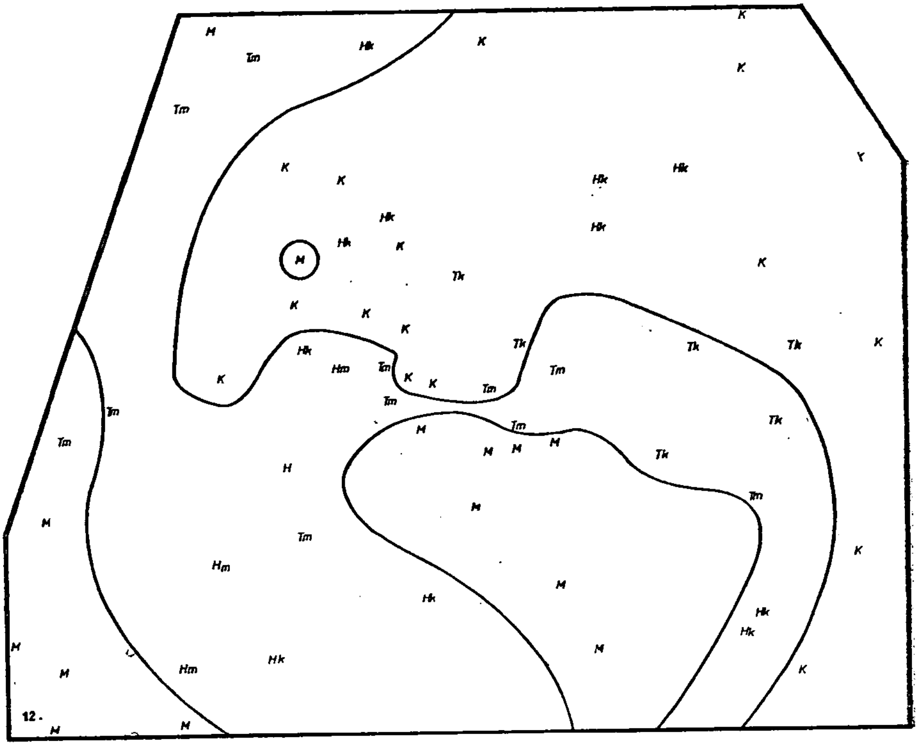


Fig. 12. Areas of Mediterranian (M) and Continental (K)-like rainfalls in summer-autumn relation)

THE HOMOGENIOUS TEMPERATURE SERIES AT SZEGED FOR 110 YEARS (1871—1980)

by

P. Sindely

Szeged 110 éves homogén hőmérsékleti sora (1871—1980). A tanulmány Szeged havi hőmérsékleti középértékeinek homogenizálásával foglalkozik. A meteorológiai állomás helye ugyanis az észlelések megindulása (1871) óta többször változott a városban.

A homogenizált sorok a város területén kívül telepített, jelenleg működő meteorológiai állomásra vonatkoznak.

The study deals with the homogenising of the data of mean monthly temperatures at Szeged. Namely the exposure of the meteorological station has changed several times inside the town since the beginning of the meteorological observations (1871).

The homogenised series refer to the present meteorological station located outside the town.

In 1871 systematic meteorological observations started in Szeged and since then — with the exception of an interruption in 1944 — they are still recorded. The site of the instruments, however, the instruments themselves and the staff working with them have continuously been changing, in this way the original observation material covering now more than 110 years is not homogenous, the data agglomeration consists of 7—8 different materials.

Especially temperature data were so much influenced by exposural and other changes that data originating from different exposures can only be compared with each other and with data originating from other stations, if the different series — with the help of an appropriate method — were united with reference to a single exposure, i. e. they were homogenised before processing. The significance of meteorological observation data of satisfying length great is from both scientific and practical point of view. The longer the homogenous observation data series at our disposal, the more exact and clearer picture can be obtained about meteorological conditions in our territory, about thea verage and extrem values of various elements (temperature, precipitation), about the frequency of certain value groups [8].

There are only five longer homogenous series of temperature observation in Hungary. In the work published in 1948 by *Bacsó* [2] contains 165 years of the Budapest series (1780—1945), while the series of Mosonmagyaróvár, Nyíregyháza and Szeged contain 75 years (1871—1945) each. Supplementing above data Pécs joined in a work of *Ferenc Simor* published in 1952 [8] representing southern Transdanubia with 80 years of homogenous temperature series. Present day homogenous temperature series naturally supplement above data. The series in Szeged from 1871 to 1924 was homogenised by *Lajos Steiner* and from 1925 to 1945 by *Bacsó*. The data of the homogenous series refer to the installation at the university sports ground from 1927 to 1944. *Ferenc Simor* — with the help of Kalocsa and Békéscsaba — established the difference between the sports ground exposure and the roof terrace exposure which is in existence since April 1946, applying the obtained difference series to the original roof terrace data he supplemented the homogenised series of *Steiner—Bacsó* up to 1955 [10].

Only the series of Mosonmagyaróvár and Nyíregyháza originate from a sufficiently free exposure, in this way the data of series in Szeged, Budapest, Pécs posess an influenced characteristic because of the installation of the various stations. In case of the last stations the town-clima effects which characterise towns have a stronger predominance [7, 11].

On the basis of above mentioned it was found necessary to complete previous homogenising calculations referring to Szeged and on a wider basis, a larger scale. The most obvious solution was found in transforming every data to the airport exposure. This station has the advantage of being a more free exposure compared to the station at the university, moreover future observations can be directly attached to the homogenised series.

A historical survey of meteorological observations in Szeged

The first meteorological observation station was established in the military hospital of that time in 1853. The climatologic research station was reorganised in the Piarist Gymnasium in 1870. Observations were made by the teachers of the gymnasium at the station which was established at the same time as the National Institute of

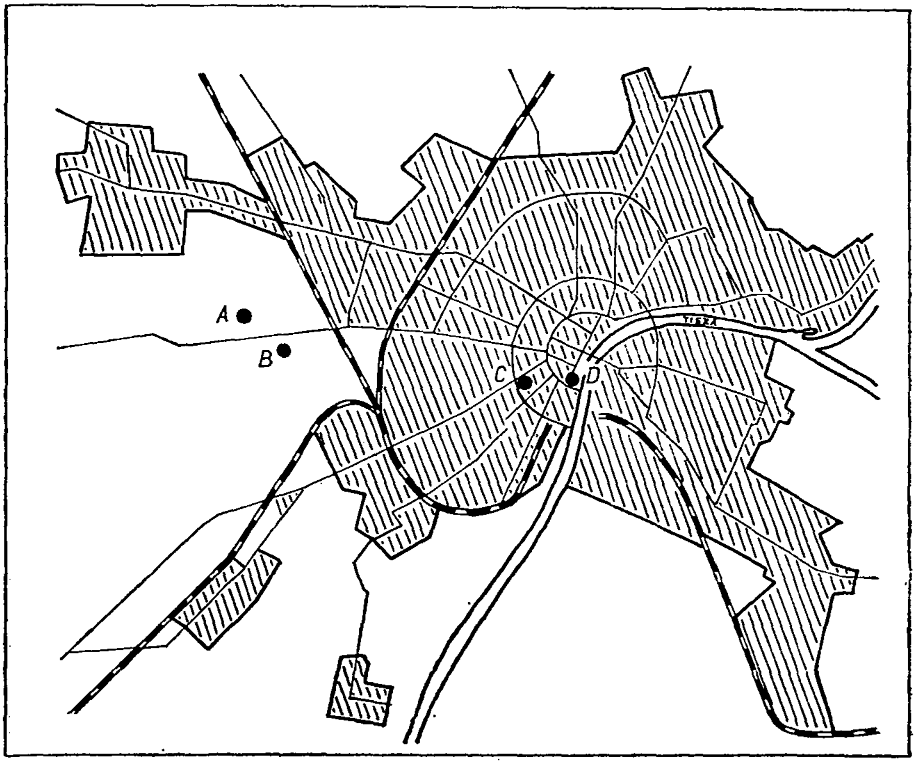


Fig. 1. Territorial situation of meteorological stations in Szeged

Meteorology. Meteorological telegrams were sent by the school as well until 4 April 1929 [1,6]. The station's psychrometer was installed in the northern side of the gymnasium's building (northern part of Beloiannisz square) in front of a ground-floor window, in a distance of 75 cm from the window. The times of observation were 7 hours, 14 hours and 21 hours [3]. The station as such ceased to exist on 31 December 1929. The continuation of observations recorded for nearly 60 years uninterruptedly by the Piarist Gymnasium was taken over by a station installed at the university in January 1927, run by the Institut of Geography at the university. During the period between 1927 and August 1944 the temperature measuring huts stood on the Ady square of today, on the border of the university sport ground in 97 m altitude.

The station, which had been destroyed during the war, was rebuilt in April 1946, where the measuring huts were placed on the roof terrace of the university on Ady square in 24 m altitude above ground level. The new station with the management of professsional observers became a synoptic main station. The observations were continued even when the station lost its main station characteristic in February 1951. From February 1951 for exactly ten years the main synoptic station functioned near the station building of the airport. In January 1961 the station moved to its own building in the immediate vicinity of the airport, 800 m far from its previous location. Since then measurements are taken here (Weather forecast station of the National Meteorological Service).

The territorial location of meteorological stations in Szeged is illustrated in *Fig. 1*.

Definition of homogenous temperature series of Szeged

The climatolgical regularity (Lamont, Hahn) that the course of weather within a greater area is nearly identical has long ago been recognised. This way the differences between homogenous temperature mean values (monthly, yearly) originating from two attaching territories with nearly identical climatological endowments and experienced during the same period are constant and exposed to a low-scale fluctuation only [9]. Homogenous series of sufficient length offer a thorough information about the alteration of climatologic elements, the size of extremities, fluctuation and changeability, about the frequency of the different value groups.

The exposure of climatologic research station built in Szeged at the function of the rivers Tisza and Maros has been more times changed. Its thermometer exposures were mostly of municipal characteristics and especially older data originate from closed installations. Not homogenous observation material is at our disposal in Szeged for the period between 1871 and 1981. Data from different observation points in town and the airport data representing the outskirts of the town show a significant difference [7, 11].

In the course of our work the homogenising of temperature series of Szeged was done for the *real (24 hours) temperature averages* instead of calculating termin-averages with various hour combinations. This way every observation has been laid on a uniform base.

The processed real (24 hours) temperature data originate from stations listed in *Tab. 1.* The table gives the names of the various stations, their period of functioning (with an interruption of a few months) as well as the duration of homogenous temperature series of this study.

The differences of averages between the homogenous series of two places for the period of 8—10 years are nearly of the same value as the divergences of homogenous

Table 1

Data of station-net considered while homogenising

Station	Years of functioning	Duration of considered homogenous temperature data
Arad	1871—	1880—1909
Ásotthalom (Királyhalom)	1892—1918	1911—1918
	1922—1972	1927—1971
Kalocsa (astronomical observatory)	1872—	1873—1909
Szeged-gymnasium	1871—1929	1871—1880
		1881—1899
		1900—1926
Szeged-university (sport grounds)	1927—1944	1927—1944
Szeged-university (roof terrace)	1946—1971	1946—1971
Szeged-Agricultural Institute (Scientific Institute of the Great Hungarian Plain)	1929—1954	1929—1944
		1948—1954
Szeged airport (previous exposure)	1951—1960	1951—1960
Szeged airport (new exposure)	1961—	1961—

series originating from the same observation period of 30—40 years length [8]. The *Hahn* difference method is based upon the practical application of above climatic regularity which is essentially as follows: if there is a reliable station with sufficient series in the vicinity, with the help of series the differences of inherently homogenous temperature series caused by the change in exposure can be justified and investigated (in present case the successive exposures in Szeged). In order to unit these different series first of all we had to determine the rate of difference between individual exposures and between the obtained series.

Our homogeneity calculations were correlated with the new airport exposure. The station's immediate vicinity has been completely free of buildings (and it still is) during observations. Taking this into account the data originating from the period which started in January 1961 and still lasts can be regarded homogenous, this way the real (24 hours) temperature means were left untouched. Observation data of the future can be directly joined to the homogenous series.

To determine the differences (Δ) between the individual exposures the following signs were applied:

(Δ1): Szeged airport (present exposure) — Szeged airport (previous exposure) °C (Tab. 2)
(Δ2): Szeged airport (present exposure) — Szeged university (roof terrace) °C (Tab. 3)
(Δ3): Szeged airport (present exposure) — Szeged university (sport grounds) °C (Tab. 4)
(Δ4) Szeged airport (present exposure) — Szeged Gymnasium (exposure III) °C (Tab. 5)
(Δ5): Szeged airport (present exposure) — Szeged Gymnasium (exposure II) °C (Tab. 6)
(Δ6): Szeged airport (present exposure) — Szeged Gymnasium (exposure I) °C (Tab. 7)

a) Determination of the difference between the present and previous airport exposure ($\Delta 1$)

From February 1951 meteorological measurements were taken in the vicinity of the airport's traffic building. In January 1961 the meteorological station was transferred to the immediate vicinity of the airport , ca. 800 m far from the original exposure. Today measurements are taken here. The difference ($\Delta 1$) between the previous and the present exposure was determined with the help of homogenous data of Szeged university (roof terrace) and Ásotthalom. The differences of monthly and yearly mean values of real (24 hours) temperatures were calculated for the previous exposure at Szeged airport and at the university's roof terrace (March 1951—December 1960) as well as for the present exposure at Szeged airport and the roof terrace of Szeged university (January 1961—December 1971). The two different airport exposures were compared with data from Ásotthalom regarding previous periods. The difference between the two exposures was obtained from the averages of difference series, i. e. if the present airport exposure was colder or warmer than the previous one. The obtained results are listed in *Table 2.*

Table 2

Demonstration of the difference between the previous and present exposure at Szeged airport, °C ($\Delta 1$)

1. Szeged airport (previous exposure) — Szeged university (roof terrace) March 1951—December 1960
2. Szeged airport (present exposure) — Szeged university (roof terrace) January 1961—December 1971

3. Szeged airport (present exposure) — Szeged airport (previous exposure)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	−0,4	−0,6	−0,5	−0,4	−0,5	−0,5	−0,7	−0,8	−0,8	−0,7	−0,4	−0,3	−0,6	°C
2.	−0,6	−0,4	−0,4	−0,6	−0,6	−0,5	−0,6	−0,9	−0,7	−0,9	−0,4	−0,3	−0,6	°C
3.	−0,2	0,2	0,1	−0,2	−0,1	0,0	0,1	−0,1	0,1	−0,2	0,0	0,0	0,0	°C

1. Szeged airport (previous exposure) — Ásotthalom March 1951—Dcember 1960
2. Szeged airport (present exposure) — Ásotthalom January 1961—December 1971

3. Szeged airport (present exposure) — Szeged airport (previous exposure)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	−0,2	−0,2	0,1	−0,1	−0,1	0,1	0,2	0,2	0,3	0,3	0,1	0,1	0,1	°C
2.	−0,1	−0,2	0,2	0,1	0,1	0,1	0,2	0,1	0,0	0,1	0,1	0,2	0,1	°C
3.	0,1	0,0	0,1	0,2	0,2	0,0	0,0	−0,1	−0,3	−0,2	0,0	0,1	0,0	°C

Szeged airport (present exposure) — Szeged airport (previous exposure) (Szeged university, Ásotthalom)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
$\Delta 1$	−0,1	0,1	0,0	0,0	0,0	0,0	0,1	−0,1	−0,1	−0,2	−0,0	0,0	0,0	°C

b) Determination of difference between exposure at Szeged airport (present) and at Szeged university (terrace) ($\Delta 2$)

As previously outlined the individually homogenous temperature data of university terrace exposure and the present airport exposure data was compared ($\Delta 2$). Calculations were based upon datas of parallel observations made during the period between January 1961 and December 1971. The yearly course of the difference between the two exposures is illustrated in *Tab. 3.* The dates make evident the climainfluencing effect of the town. It can be stated that the real (24 hours) temperature means of the airport representing the outskirts of the town are unanimously lower than the temperatures measured in town. This difference amounts to an average of 0,6 °C per year.

Table 3

Real temperature differences between Szeged airport (present exposure) and Szeged university (roof terrace), °C, $\Delta 2$ January 1961—December 1971

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
−0,6	−0,4	−0,4	−0,6	−0,6	−0,5	−0,6	−0,9	−0,7	−0,9	−0,4	−0,3	−0,6

c) Determination of difference between exposures at Szeged airport (present) and Szeged university (sport grounds) ($\Delta 3$)

The temperature measuring huts stood in downtown on the border of the university's sport grounds during the period from 1927 to 1944. Since the station had been destroyed during the war a new one was placed on the roof terrace of the Geographical Institute of the University in April 1946. The terrace lies in 24 m altitude above ground level. Consequently, the placing of the university station was altered and because of the war no observations were made during 1945. The missing data (monthly and yearly real temperature data) was supplied by stations at Kalocsa, Ásotthalom and at the Agricultural Institute in Szeged. Homogenous mean values transferred to the airport station are given in *Tab. 4.*

The definition of real temperature differences caused by exposure change at Szeged university (terrace and sport grounds) was based upon measurements made by a station at Ásotthalom and at the Agricultural Institute of Szeged (which is called Scientific Institution of the Great Hungarian Plain from 1950). Subsequently the difference data series of the university sport grounds was first transferred to the university roof terrace exposure and afterwards to the present airport exposure. A demonstration of the difference between the exposures at the university sport grounds and at the airport is given in *Tab. 4.*

d) Determination of difference between exposures at Szeged Gymnasium and airport ($\Delta 4$, $\Delta 5$, $\Delta 6$)

In Szeged meteorological measurements were taken at the Piarist Gymnasium of that time from 1871 to 31 December 1929, when the station ceased to exist. Measurements were subsequently transferred to the university exposure. The installation at the gymnasium was altered in 1881, 1889 and in 1900 [4, 5]. The influence caused by

Table 4

Demonstration of the difference between the university (sport grounds) and the airport exposure, °C, (Δ3)

1. Szeged university (sport grounds) — Ásotthalom January 1927—December 1971
2. Szeged university (terrace) — Ásotthalom April 1946—December 1971

3. Szeged university (terrace) — Szeged university (sport grounds)

	I	II	III	IV	V	VI	VII	VIII	IX	X	X	XI	XII	Year
1.	0,3	0,4	0,6	0,4	0,5	0,6	0,6	0,7	0,8	0,7	0,5	0,5	0,5	°C
2.	0,4	0,3	0,5	0,5	0,5	0,7	0,9	1,0	1,0	0,9	0,5	0,5	0,6	°C
3.	0,1	−0,1	−0,1	−0,1	−0,2	0,1	0,3	0,3	0,2	0,2	0,0	0,0	0,1	°C

1. Szeged university (sport grounds) — Szeged Agricultural Institut January 1929—May 1944
2. Szeged university (terrace) — Szeged agricultural Institut June 1948—December 1954

3. Szeged university (terrace) — Szeged university (sport grounds)

1.	0,1	0,2	0,1	0,1	−0,1	0,0	0,1	0,0	0,1	0,1	0,1	0,1	0,1	°C
2.	0,0	0,1	0,0	0,1	0,2	0,2	0,2	0,0	0,1	0,3	0,0	0,1	0,1	°C
3.	−0,1	−0,1	−0,1	0,0	0,3	0,2	0,1	0,0	0,0	0,2	−0,1	0,0	0,0	°C

1. Szeged university (terrace) — Szeged university (sport grounds) (Ásotthalom, Szeged Agricultural Institut)
2. Szeged airport (present exposure) — Szeged university (terrace)

3. Szeged airport (present exposure) — Szeged university (sport grounds)

1.	0,0	−0,1	−0,1	0,0	0,1	0,2	0,2	0,1	0,1	0,2	−0,1	0,0	0,05	°C
2.	−0,6	−0,4	−0,4	−0,6	−0,6	−0,5	−0,6	−0,9	−0,7	−0,9	−0,4	−0,3	−0,6	°C
Δ3	−0,6	−0,5	−0,5	−0,6	−0,5	−0,3	−0,4	−0,8	−0,6	−0,7	−0,5	−0,3	−0,55	°C

several exposural modifications cannot be demonstrated by comparing the real temperature averages of Kalocsa and Arad in 1889. Between the individual members of the individual columns of monthly and yearly real temperature difference series no sudden change can be experienced, so homogenisation was not disturbed by this. Three different, individually homogenous (but compared with each other not homogenous) series are differentiated, as follows: gymnasium exposure I, (1871—1880), gymnasium, exposure II (1881—1899), gymnasium, exposure III (1900—1929).

Following the previously outlined method on the basis of data from more stations (Kalocsa, Ásotthalom, Arad) the differences between the real temperature averages between the three stations and the exposures at the gymnasium were one by one determined. Temperature differences between gymnasium exposure III (1900—1927) and the university sport grounds exposure were determined by the individually homogenous temperatures of Ásotthalom (Királyhalom) and Kalocsa. On the basis of this data and the differences of the airport and university exposures the difference between Szeged airport (present) exposure and Szeged gymnasium (exposure III) (Δ4) was demonstrated, as illustrated in *Tab. 5*.

The temperature data of gymnasium exposure II (1881—1899) was homogenised with the help of temperature data of Kalocsa and Arad [4] and it was transformed to gymnasium exposure III as well as to the exposure at the airport (Δ5). Calculated data is shown in *Tab. 6*.

Table 5

Demonstration of the difference between Szeged airport (present exposure) and Szeged gymnasium (exposure III), °C, ($\Delta 4$)

1. Szeged gymnasium (exposure III)—Ásotthalom 1911—1917, 1924—1928
2. Szeged university (sport grounds)—Ásotthalom January 1927—August 1944

3. Szeged university (sport grounds) — Szeged gymnasium (exposure III)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	0,3	0,3	0,3	0,4	0,4	0,4	0,5	0,6	0,4	0,4	0,4	0,4	0,4	°C
2.	0,3	0,4	0,6	0,4	0,5	0,6	0,6	0,7	0,8	0,7	0,5	0,5	0,5	°C
3.	0,0	0,1	0,3	0,0	0,1	0,2	0,1	0,1	0,4	0,3	0,1	0,1	0,1	°C

1. Szeged gymnasium (exposure III) — Kalocsa (astronomical observatory) 1911—1926
2. Szeged university (sport grounds) — Kalocsa (astronomical observatory) January 1927—August 1944

3. Szeged university (sport grounds) — Szeged gymnasium (exposure III)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	0,2	0,2	0,2	0,5	0,3	0,6	0,4	0,3	0,2	0,4	0,6	0,4	0,4	°C
2.	0,2	0,1	0,3	0,4	0,5	0,5	0,5	0,4	0,4	0,5	0,4	0,4	0,4	°C
3.	0,0	0,1	0,1	−0,1	0,2	−0,1	0,1	0,1	0,2	0,1	−0,2	0,0	0,0	°C

1. Szeged university (sport grounds) — Szeged gymnasium (exposure III) 1900—1926
2. Szeged airport (present exposure) — Szeged university (sport grounds)

3. Szeged airport (present exposure) — Szeged gymnasium (exposure III) 1900—1926

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	0,0	0,1	0,2	0,0	0,1	0,1	0,1	0,1	0,3	0,2	0,0	0,1	0,1	°C
2.	−0,6	−0,5	−0,5	−0,6	−0,5	−0,3	−0,4	−0,8	−0,6	−0,7	−0,5	−0,3	−0,5	°C
$\Delta 4$	−0,6	−0,4	−0,3	−0,6	−0,4	−0,2	−0,3	−0,7	−0,3	−0,5	−0,5	−0,2	−0,4	°C

Table 6

Demonstration of the difference between Szeged airport (present exposure) and Szeged gymnasium (exposure II), °C, ($\Delta 5$)

1. Szeged gymnasium (exposure II) — Arad 1881—1899
2. Szeged gymnasium (exposure III) — Arad 1900—1909

3. Szeged gymnasium (1900—1909) — Szeged gymnasium (1881—1899)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	−0,1	0,0	0,0	0,0	0,1	0,2	0,2	−0,1	−0,1	−0,2	−0,2	−0,2	0,0	°C
2.	−0,7	−0,6	−0,3	0,1	0,0	0,1	0,1	−0,1	−0,2	−0,4	−0,7	−0,6	−0,3	°C
3.	−0,6	−0,6	−0,3	0,1	−0,1	−0,1	−0,1	0,0	−0,1	−0,2	−0,5	−0,4	−0,3	°C

1. Szeged gymnasium (exposure II) — Kalocsa 1881—1899
2. Szeged gymnasium (exposure III) — Kalocsa 1900—1909

3. Szeged gymnasium (1900—1909) — Szeged gymnasium (1881—1899)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	−0,6	−0,7	−0,4	−0,1	−0,2	−0,1	−0,1	−0,5	−0,6	−0,3	−0,5	−0,5	−0,4	°C
2.	−0,4	−0,4	−0,3	−0,4	−0,1	−0,5	−0,2	−0,5	−0,3	−0,2	−0,1	−0,1	−0,3	°C
3.	0,2	0,3	0,1	−0,3	0,1	−0,4	−0,1	0,0	0,3	0,1	0,4	0,4	0,1	°C

1. Szeged gymnasium (exposure III) — Szeged gymnasium (exposure II), (Arad, Kalocsa)
2. Szeged airport (present exposure) — Szeged gymnasium (exposure III), 1900—1926

3. Szeged airport (present exposure) — Szeged gymnasium (exposure II) 1881—1899

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	−0,1	−0,1	−0,1	−0,1	0,0	−0,2	−0,1	0,0	0,1	0,1	0,0	0,0	−0,1	°C
2.	−0,6	−0,4	−0,3	−0,6	−0,4	−0,2	−0,3	−0,7	−0,3	−0,5	−0,5	−0,2	−0,4	°C
$\Delta 5$	−0,7	−0,5	−0,4	−0,7	−0,4	−0,4	−0,2	−0,7	−0,2	−0,4	−0,5	−0,2	−0,5	°C

The temperature data from 1871 to 1879 (gymnasium exposure I) was correlated with homogenous data from Kalocsa (1873—1899), the obtained data was transferred to data representing the outskirts of town ($\Delta 6$). The results of our calculations are listed in *Tab. 7*.

Table 7

Demonstration of the difference between Szeged airport (present exposure) and Szeged gymnasium (exposure I), °C, ($\Delta 6$)

1. Szeged-gymnasium (exposure I) — Kalocsa 1873—1880
2. Szeged-gymnasium (exposure II) — Kalocsa 1881—1899

3. Szeged-gymnasium (1881—1899) — Szeged-gymnasium (1871—1880)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year	
1.	−0,4	−0,8	−0,4	0,0	0,0	−0,3	−0,1	−0,6	−0,3	−0,2	−0,2	−0,1	−0,3	°C
2.	−0,6	−0,7	−0,4	−0,1	−0,2	−0,1	−0,1	−0,5	−0,6	−0,3	−0,5	−0,5	−0,4	°C
3.	−0,2	0,1	0,0	−0,1	−0,2	0,2	0,0	0,1	−0,3	−0,1	−0,3	−0,4	−0,1	°C

1. Szeged-gymnasium (1881—1899) Szeged-gymnasium (1871—1880)
2. Szeged-airport (present exposure) — Szeged gymnasium (1881—1899)

3. Szeged-airport (present exposure) — Szeged gymnasium (1871—1899)

1.	−0,2	0,1	0,0	−0,1	−0,2	0,2	0,0	0,1	−0,3	−0,1	—0,3	−0,4	−0,1	°C
2.	−0,7	−0,5	−0,4	−0,7	−0,4	−0,4	−0,4	−0,7	−0,2	−0,4	−0,5	−0,2	−0,5	°C
$\Delta 6$	−0,9	−0,4	−0,4	−0,1	−0,6	−0,2	−0,4	−0,6	−0,5	−0,5	−0,8	−0,6	−0,6	°C

Table 8

Corrections applied in the course of combining real (24 hours) temperature data (°C)

	$\Delta 1$	$\Delta 2$	$\Delta 3$	$\Delta 4$	$\Delta 5$	$\Delta 6$
January	−0,1	−0,6	−0,6	−0,6	−0,7	−0,9
February	0,1	−0,4	−0,5	−0,4	−0,5	−0,4
March	0,0	−0,4	−0,5	−0,3	−0,4	−0,4
April	0,0	−0,6	−0,6	−0,6	−0,7	−0,8
May	0,0	−0,6	−0,5	−0,4	−0,4	−0,6
June	0,0	−0,5	−0,3	−0,2	−0,4	−0,2
July	0,1	−0,6	−0,4	−0,3	−0,4	−0,4
August	−0,1	−0,9	−0,8	−0,7	−0,7	−0,6
September	−0,1	−0,7	−0,6	−0,3	−0,2	−0,5
October	−0,2	−0,9	−0,7	−0,5	−0,4	−0,5
November	0,0	−0,4	−0,5	−0,5	−0,5	−0,8
December	0,0	−0,3	−0,3	−0,2	−0,2	−0,6
Year	0,0	−0,6	−0,5	−0,4	−0,5	−0,6

Designation:

$\Delta 1$: Szeged airport (present exposure) — Szeged airport (previous exposure)
$\Delta 2$: Szeged airport (present exposure) — Szeged university (terrace)
$\Delta 2$: Szeged airport (present exposure) — Szeged university (sport grounds)
$\Delta 4$: Szeged airport (present exposure) – Szeged gymnasium (exposure III)
$\Delta 5$: Szeged airport (present exposure) — Szeged gymnasium (exposure II)
$\Delta 6$: Szeged airport (present exposure) — Szeged gymnasium (exposure I)

Table 9

The homogenous temperature series at Szeged
1871—1980

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1871	−1,9	0,1	5,6	9,8	15,6	20,0	22,9	21,4	17,2	8,6	4,6	−8,2	9,6
1872	−2,4	0,0	6,8	13,0	18,8	18,3	21,1	19,5	16,5	13,7	7,4	3,6	11,3
1873	0,4	2,0	8,7	10,5	13,8	19,0	23,3	22,2	15,8	13,9	5,7	−1,3	11,0
1874	−2,7	−1,7	2,3	12,7	11,9	21,0	24,3	20,1	18,0	10,2	0,3	1,2	9,8
1875	−2,3	−7,5	*−2,1*	8,7	16,0	22,5	21,6	20,5	14,6	9,7	3,4	−2,9	8,5
1876	−7,5	−0,6	7,6	13,8	12,7	20,2	21,0	21,6	14,9	13,2	−0,2	3,5	10,0
1877	0,8	1,8	5,3	9,4	13,2	19,9	20,1	21,9	13,2	7,7	4,9	−0,2	10,1
1878	−4,2	1,1	3,8	10,3	15,9	19,2	19,6	20,5	18,3	12,6	6,2	−0,6	10,1
1879	−2,8	3,8	4,4	10,8	14,8	21,4	19,7	20,7	17,7	9,3	0,9	*−10,4*	8,8
1880	−6,4	−2,6	2,8	13,4	14,5	19,1	23,1	17,7	15,8	10,4	5,1	3,1	9,6
1881	−4,9	−2,3	4,9	8,7	15,3	18,5	21,3	20,6	15,6	8,6	2,5	−0,3	9,0
1882	−0,4	0,7	*9,7*	10,7	15,7	16,9	21,8	17,8	17,1	12,0	5,8	2,5	10,8
1883	−2,8	0,3	1,0	8,4	15,7	19,3	21,7	19,7	15,9	10,8	4,8	−0,5	10,5
1884	−0,4	2,4	6,1	9,2	16,4	16,5	20,2	18,3	16,3	9,0	0,3	1,0	10,5
1885	−2,4	2,1	6,2	13,0	15,0	20,6	21,6	18,9	17,0	11,7	5,8	−3,7	10,4
1886	−0,1	−1,5	2,1	11,2	16,5	18,8	21,7	21,0	18,3	12,2	5,7	2,5	10,7
1887	−2,0	−2,9	3,4	10,2	16,1	18,2	24,0	21,2	18,1	8,9	5,8	−1,5	9,9
1888	−7,9	−5,2	4,6	10,2	16,6	21,2	21,4	20,3	17,9	9,8	0,6	0,2	9,1
1889	−3,8	−1,9	2,4	10,2	18,9	22,2	22,8	20,9	13,8	13,1	4,3	−5,4	9,7
1890	−1,2	−1,8	5,5	11,5	17,8	18,3	22,9	24,3	15,2	9,5	6,0	−3,4	10,3
1891	−8,2	−6,0	3,2	8,2	18,5	20,0	22,3	20,8	17,1	12,8	5,1	1,2	9,6
1892	−1,7	1,0	3,0	11,2	16,6	20,6	21,6	22,9	19,9	11,9	2,4	−3,2	10,5
1893	*−11,2*	−1,4	4,9	9,3	15,8	19,1	21,6	19,0	16,1	12,5	4,9	1,5	9,3
1894	−4,0	0,7	6,1	13,6	16,8	18,8	24,6	21,2	15,7	12,3	4,5	−0,8	10,7
1895	−2,2	−6,3	2,8	10,4	16,4	19,6	22,9	20,1	17,3	11,2	5,5	0,1	9,8
1896	−8,2	−1,0	6,4	8,0	15,4	19,9	21,4	19,3	16,9	14,5	3,7	1,6	9,8
1897	−0,7	0,9	7,5	11,2	14,4	19,4	21,1	20,8	17,4	8,9	1,5	−2,4	10,0
1898	−1,0	0,7	6,1	11,9	16,3	19,0	19,5	20,5	16,2	12,1	7,1	1,6	10,8
1899	1,7	1,8	4,0	11,7	15,3	*17,1*	20,6	19,7	16,6	9,1	5,4	−2,5	10,0
1900	0,8	5,1	3,2	10,4	15,8	20,1	23,2	19,9	16,9	12,0	7,2	1,2	11,3
1901	−7,5	−3,8	6,2	10,4	16,2	20,6	22,2	19,5	15,8	11,9	2,9	4,0	9,9
1902	1,3	2,9	4,3	9,4	12,2	18,5	20,3	21,0	16,3	10,6	1,4	−4,9	9,4
1903	−2,5	3,1	8,1	7,9	15,4	17,9	20,5	19,4	17,3	11,2	6,2	2,4	10,6
1904	−2,6	2,9	5,3	11,0	15,8	19,5	23,5	21,2	15,3	10,9	2,6	1,2	10,5
1905	−6,5	0,1	5,6	9,1	16,3	20,5	23,8	22,4	18,5	*6,2*	6,8	1,3	10,3
1906	−2,4	0,4	5,6	11,3	16,2	18,8	21,8	19,9	15,0	10,6	7,0	−1,3	10,3
1907	−3,3	−3,1	1,9	7,7	18,9	20,1	20,2	20,6	16,6	*15,8*	3,9	2,4	10,2
1908	−3,2	0,3	4,8	9,4	19,0	21,4	21,5	18,9	15,2	9,5	*−0,9*	−0,9	9,6
1909	−3,7	−3,7	5,7	10,9	15,4	19,3	20,4	21,8	17,5	12,9	3,8	4,4	10,4
1910	0,7	4,5	6,2	10,2	15,9	20,1	21,0	20,2	15,3	10,7	4,1	4,0	11,1
1911	0,0	−2,1	5,7	9,8	15,9	19,0	23,0	21,4	17,3	11,3	8,0	3,0	11,1
1912	−3,7	3,2	8,2	8,1	14,9	20,3	21,6	18,3	*11,5*	8,3	2,7	1,9	9,6
1913	−2,5	−1,0	7,9	10,4	14,6	18,7	*18,4*	18,0	16,5	11,3	6,0	1,5	10,0
1914	−6,6	−3,7	6,8	11,8	15,3	18,2	19,9	20,2	15,0	9,7	2,9	3,2	9,4
1915	1,5	1,3	3,7	9,6	16,0	20,4	20,3	17,8	13,4	9,4	3,0	4,7	10,1
1916	2,1	0,9	9,3	10,5	15,7	19,2	21,4	19,5	14,8	10,3	7,1	4,8	11,3
1917	0,1	−6,3	4,3	9,6	16,7	21,1	21,4	22,3	18,6	12,3	6,2	−1,1	10,5
1918	0,4	0,7	5,8	14,0	16,1	17,9	20,9	19,9	18,5	11,6	3,4	1,0	10,9

Table 9

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1919	2,7	0,6	6,5	10,1	*11,4*	19,1	19,8	19,4	18,1	9,7	4,6	0,5	10,2
1920	2,0	1,2	7,1	*14,7*	18,5	19,1	22,4	19,5	17,1	7,9	0,7	3,0	11,1
1921	3,4	1,2	7,8	10,6	18,1	18,5	23,6	22,3	16,1	11,6	2,8	0,0	11,4
1922	−3,0	−4,7	7,3	9,4	16,7	20,6	22,4	21,1	15,7	8,9	2,5	2,1	10,2
1923	0,9	1,5	6,8	9,9	18,6	17,8	22,5	21,0	18,1	14,2	8,4	1,7	11,8
1924	−4,6	−0,7	4,4	10,0	18,7	21,4	21,8	19,2	18,4	11,3	3,1	0,3	10,3
1925	0,1	5,9	5,3	11,7	17,5	18,5	22,5	21,3	16,0	12,0	6,3	−2,6	11,2
1926	−0,2	4,6	4,9	13,0	15,6	18,8	20,4	18,6	18,1	12,6	*11,4*	1,5	11,6
1927	1,8	−0,3	8,6	10,6	15,4	21,9	23,2	21,8	18,2	10,7	6,2	−2,7	11,3
1928	−2,3	0,5	3,8	11,9	13,6	18,8	*25,0*	21,7	17,6	10,5	7,3	−0,6	10,7
1929	−4,2	−8,9	2,3	*7,3*	17,6	19,2	21,6	22,7	16,7	13,1	7,2	2,3	9,8
1930	0,1	1,4	7,5	12,0	15,5	21,9	22,5	20,6	18,6	11,4	7,7	1,0	11,7
1931	−0,4	1,7	2,2	8,8	18,6	22,3	23,2	20,6	12,8	9,7	4,6	−1,1	10,2
1932	−3,2	−7,2	−0,8	10,3	17,0	18,7	23,5	21,4	20,5	12,7	4,6	0,7	9,9
1933	−3,3	1,2	5,8	7,7	14,3	17,3	21,7	20,4	15,8	11,5	6,1	−5,7	9,5
1934	−2,8	0,2	9,6	14,5	18,8	19,2	21,6	21,5	18,1	11,5	7,2	*4,9*	*12,0*
1935	−4,2	−1,5	4,1	10,7	15,1	22,0	21,8	20,6	16,8	14,5	4,9	2,4	10,6
1936	4,4	2,2	8,7	11,3	17,3	19,5	24,2	19,1	15,8	6,7	4,7	0,4	11,2
1937	−2,8	2,0	8,3	10,3	18,6	21,0	21,3	19,7	18,4	11,3	5,8	1,3	11,3
1938	−1,8	0,9	7,8	8,2	14,6	22,0	22,5	20,7	15,9	12,0	6,8	−0,7	10,8
1939	0,6	2,1	3,5	13,7	15,5	20,4	23,0	21,0	16,3	10,1	5,5	0,3	11,0
1940	−8,6	−5,8	2,0	10,7	14,0	18,6	20,9	*17,0*	16,6	11,1	7,7	−5,2	*8,2*
1941	−2,4	3,2	6,0	10,6	13,9	18,4	20,8	19,5	13,4	9,5	2,5	0,6	9,6
1942	−9,5	−3,7	1,9	9,1	16,6	20,1	21,6	21,2	20,3	12,0	3,7	2,1	9,6
1943	−4,7	2,6	6,1	11,9	14,5	18,6	22,3	23,9	19,4	13,5	5,1	1,8	11,2
1944	1,1	−1,1	2,2	10,9	15,1	20,2	20,8	22,7	16,9	11,9	5,9	0,4	10,4
1945	−4,3	1,6	7,1	11,2	19,0	20,6	22,6	20,9	16,8	10,8	5,5	1,8	11,1
1946	−5,1	1,9	7,2	14,2	19,5	*22,7*	24,6	24,2	19,6	6,9	6,2	−0,8	11,7
1947	−7,7	−1,8	8,0	13,6	18,2	21,1	23,0	21,3	*20,6*	9,7	6,9	2,2	11,2
1948	*4,6*	0,9	6,5	13,0	18,0	19,3	20,4	21,7	17,8	11,7	3,3	−4,0	11,0
1949	0,9	1,8	2,8	12,5	17,2	*17,1*	20,8	19,4	17,9	12,0	7,5	2,9	11,0
1950	−3,3	1,3	7,0	12,6	18,6	21,7	24,2	23,0	17,7	9,6	5,8	4,1	11,8
1951	2,1	4,0	6,8	11,4	16,1	20,2	22,2	22,6	18,7	9,7	8,1	1,6	11,8
1952	0,8	0,8	2,9	14,4	15,4	20,6	24,2	*24,6*	16,5	10,7	5,2	1,5	11,5
1953	0,5	0,4	5,0	11,5	14,7	20,0	23,1	19,5	17,8	12,7	3,4	−1,0	10,6
1954	−7,2	−7,4	6,0	8,7	15,6	21,1	19,9	20,8	18,4	10,4	5,0	3,5	9,6
1955	−0,4	2,5	3,1	7,7	15,3	19,1	20,5	19,4	16,7	11,2	5,2	3,1	10,3
1956	1,1	*−9,3*	1,5	11,0	15,5	18,5	21,5	21,4	17,3	10,6	2,1	0,5	9,3
1957	−3,0	4,4	6,8	11,7	13,4	21,5	22,2	20,5	16,3	10,4	6,5	−0,3	10,9
1958	−2,7	4,0	1,2	8,4	*20,0*	18,8	22,8	21,8	16,6	10,8	6,3	3,5	11,0
1959	−0,7	−0,7	7,8	11,1	15,6	19,0	22,2	20,1	14,8	9,5	5,3	4,0	10,7
1960	−3,1	0,0	6,1	11,0	15,2	20,0	20,4	21,0	15,6	12,5	7,9	*4,9*	11,0
1961	−0,5	3,3	8,0	14,0	14,5	20,0	19.9	20,4	17,9	13,4	7,0	0,0	11,5
1962	0,1	−0,8	0,8	12,4	15,5	18,2	19,4	22,2	14,8	11,5	6,6	−2,2	9,9
1963	−7,8	−4,0	3,5	12,2	16,7	20,6	22,8	22,0	18,0	10,6	10,3	−4,6	10,0
1964	−9,3	−2,0	2,9	11,6	14,9	22,4	21,1	19,3	16,2	11,6	7,0	0,6	9,7
1965	0,3	−3,7	6,2	9,4	14,7	19,2	20,8	18,1	17,1	9,7	3,4	3,0	9,9
1966	−4,3	*6,0*	5,4	12,7	15,8	18,7	20,3	20,1	16,3	15,6	5,3	1,6	11,2
1967	−5,2	1,1	7,0	10,6	16,3	18,7	22,7	20,9	18,4	13,2	5,6	−0,1	10,7
1968	−1,7	3,0	5,7	13,0	17,4	20,6	20,7	18,8	16,0	10,8	7,3	−1,0	10,9

e) Combination of various temperature series (1871—1980)

After having defined the differences caused by exposural modifications of the individually homogenous temperature series obtained from successive exposures in Szeged the next step is a combination of the different series. Homogenising calculations were transformed to the present airport exposure representing the outskirts of town. The real temperature averages of the airport station measured during the period between 1961 and 1980 were left unchanged. In order to convert the original data of the individual stations in Szeged the corrections summarised in *Tab. 8.* were effectuated.

Values transformed to present airport installation are given in *Tab. 9* in this way we

Table 9

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1969	−3,9	−0,6	4,0	9,9	17,9	17,9	20,6	19,6	16,9	11,0	7,9	−2,2	9,9
1970	−1,4	0,5	4,9	10,6	14,3	19,5	20,3	20,1	15,2	9,3	7,6	0,8	10,1
1971	−1,9	2,4	2,8	11,3	18,1	18,9	20,7	21,8	14,1	9,0	4,7	2,3	10,4
1972	−0,8	3,6	7,6	12,7	16,4	20,5	21,6	19,2	13,4	8,5	5,4	0,8	10,7
1973	−0,8	2,4	5,0	9,6	17,1	19,2	21,0	20,6	17,7	9,6	2,3	−0,3	10,3
1974	1,4	5,2	7,9	9,9	14,5	17,3	19,6	22,0	16,8	7,8	5,0	2,8	10,9
1975	1,3	0,1	8,3	10,4	17,5	19,1	20,9	19,8	18,5	10,4	3,9	0,5	10,9
1976	−0,2	−1,3	2,4	11,4	15,3	17,9	21,4	17,9	15,3	11,9	6,9	0,6	10,0
1977	1,0	5,0	8,5	8,9	15,9	19,5	20,3	20,1	14,1	11,2	5,8	−2,0	10,7
1978	−0,2	0,3	6,8	9,9	13,7	18,2	19,2	18,5	14,5	10,3	1,8	1,6	9,6
1979	−2,1	2,3	7,9	9,6	17,4	21,7	18,8	19,2	16,8	9,4	5,7	4,1	10,9
1980	−4,2	1,0	5,3	8,1	13,4	18,5	19,7	20,1	15,6	11,4	4,0	−0,2	9,4

have a homogenously combined series of real temperature averages of 110 years (1871—1980) originating from different exposures in Szeged.

Characteristic features of homogenous temperature series of Szeged

The unhomogenous original temperature observation material was homogenised as previously described. Following this, the direction of temperature changes in Szeged during the past 110 years was investigated on the basis of observational data. While processing the index numbers of averages (A), standard deviation (σ) and skewness were applied as summarised in *Tab. 10*.

Table 10

Averages of the monthly mean temperature at Szeged during 110 years (1871—1980), °C

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Average (A)	−2,1	0,1	5,3	10,8	16,0	19,6	21,6	20,5	16,7	10,9	5,0	0,5	10,4
Standard deviation (s)	3,15	3,18	2,33	1,72	1,70	1,35	1,38	1,46	1,65	1,78	1,24	2,73	0,76
Skewness (α)	−0,52	−0,79	−0,46	0,24	−0,01	0,23	0,22	0,26	−0,27	0,04	−0,31	−1,07	−0,26

First 110 year averages (A=arithmetic mean value) of homogenous series consisting of monthly and yearly real (24 hours) mean temperatures were calculated on the basis of the following formula:

$$A = \frac{\sum X}{N}.$$

The monthly mean averages demonstrate that the coldest month (−2,1 °C) was January, while the warmest one appeared to be July (21,6 °C). The difference between the mean temperatures of the coldest and the warmest month, that is the value of *yearly mean oscillation* is 23,7 °C. The yearly *real temperature average is 10,4 °C in Szeged.*

In order to determine the places of the individual values around the mean values a dispersion index number, the average quadratic divergence or shortly the *standard deviation* (σ) was calculated. Thes values were determined with the following formula for the period between 1871 and 1980:

$$\sigma = \sqrt{\frac{\sum (X-A)^2}{N}}.$$

The yearly course of standard deviation values shows a characteristic picture *(Tab. 10)* it has a contrasting course with the yearly temperature course. The standard deviation of monthly mean temperatures is wider in the winter months (3,0) and more moderate during the summer months (1,4). During the winter months the great oscillation values are not so much determined by greater values of maximums but by those of minimums — December 1879, January 1893 *(Fig. 2, Tab. 11)*. The greatest negative anomalies of December mean temperatures were unanimously observed in the whole country in December 1879. In forming the yearly course of standard deviation the main role is played by advective factors. In this way during the months when the occurence of oceanic air mass appears to be the most frequent — that is, in summer, the standard deviation is lower while during the months when oceanic air masses occur less frequently consequently continental advections have a stronger influence the standard deviation is wider as well.

In a numerical expression the characteristic of divergency from normal distribution is given by the rate of skewness (α).

$$\alpha = \frac{\frac{\sum (X-A)^3}{N}}{\sqrt{\left(\frac{\sum (X-A)^2}{N}\right)^3}} = \frac{\frac{1}{N}\left[\sum X^3 - 3A\sum X^2 + 2NA^3\right]}{\sqrt{\left[\frac{1}{N}\left(\sum X^2 - NA^2\right)\right]^3}}.$$

Referring to the period between 1871 and 1980 temperature distributions approach normal distribution mostly during spring and autumn (May, October) during this interwall the value of skewness stays near zero. It appears from data in *Tab. 10* that the distribution of mean temperatures has a right skewness while during the winter months the rate of skewness is negative which means that the distribution has a left side skewness.

The extrem values of monthly and yearly mean temperatures measured in Szeged during 110 years are given in *Tab. 11* determining the rate of oscillation as well. The warmest month in Szeged appeared to be July in 1928 (25 °C) and the coldest one was January in 1893 (−11,2 °C). The temperature values of August in 1952 (24,6 °C)

Table 11

The extremes of the monthly and annual temperatures at Szeged during 110 years (1871—1980), °C

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Maximum	4,6	6,0	9,7	14,7	20,0	22,7	25,0	24,6	20,6	15,8	11,4	4,9	12,0
Year	1948	1966	1882	1920	1958	1946	1928	1952	1947	1907	1926	1960 1934	1934
Minimum	−11,2	−9,3	−2,1	7,3	11,4	17,1	18,4	17,0	11,5	6,2	−0,9	−10,4	8,2
Year	1893	1956	1875	1929	1919	1899 1949	1913	1940	1912	1905	1908	1879	1940
Variation	15,8	15,3	11,8	7,4	8,6	5,6	6,6	7,6	9,1	9,6	12,3	15,3	3,8

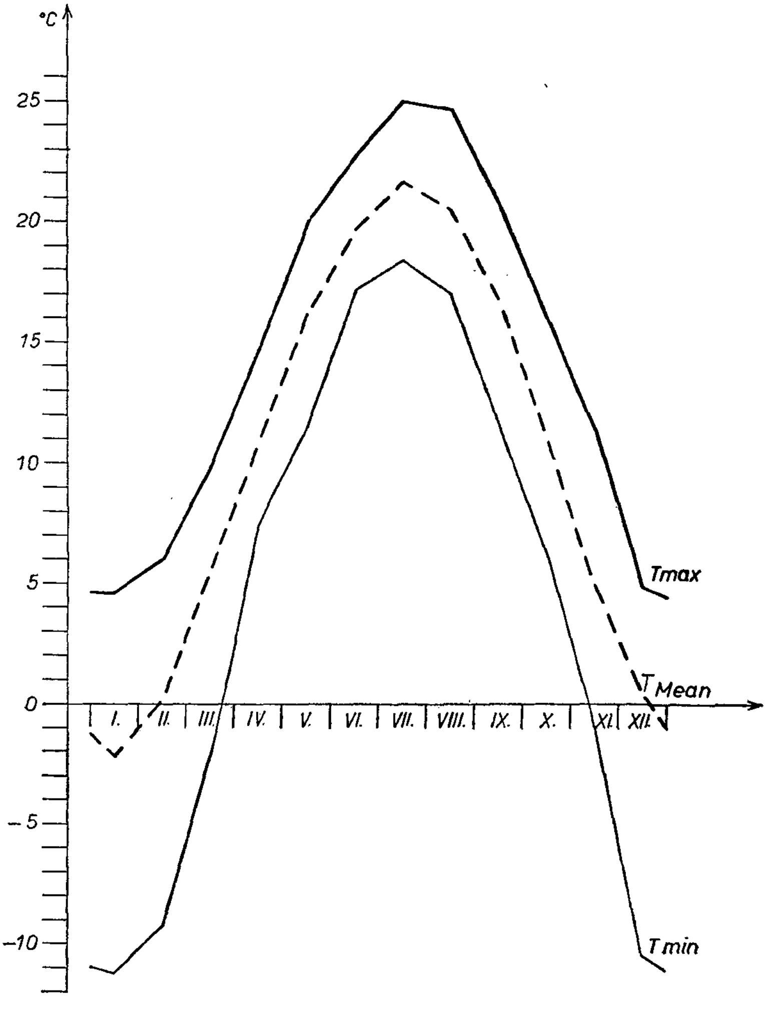


Fig. 2. Extrem values of monthly mean temperatures at Szeged (1871—1980)

and December in 1879 (−10,4 °C) are worth mentioning being of more striking character. In yearly aspect extrem values — according to other temperature data of the country — at the same time, i. e. in 1934 (max. : 12,0 °C) and in 1940 (min.: 8,2 °C). The yearly courses of extrem values and mean values are illustrated in *Fig. 2*.

By determining homogenous temperature series of Szeged a town representing the south-eastern part of the country, and by discusing the characteristic features of temperature data a contribution was made to the advancement of town-climatological researches in Szeged.

Summary

The main object of present study was to homogenise temperature data obtained in Szeged, since the exposure of climatologic research stations of the town has been more times modified. Homogenising calculations were based upon measurements made at observation stations situated at various points of the town as well as on the basis of measurements taken at the airport representing the outskirts of the town. Measurements taken during the period between 1871 and 1980 were considered. In the course of our work the homogenisation of temperature series of Szeged was done for the real (24 hours) temperature averages this way every observation was placed on a uniform basis. On the basis of the obtained homogenous series of sufficient length (1871—1980) the rate of changeability, oscillations and extrems were emphasised. The town-climatic effects characterising towns are less predominating at the airport exposure. The advantage of homogenous series converted to this exposure is that observations made in the future can be directly joined to this homogenous series.

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